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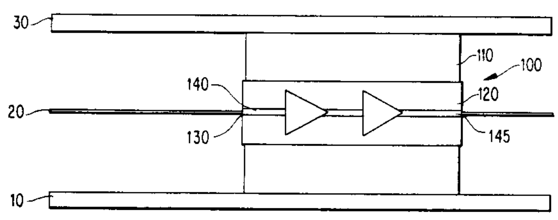
(54) Low loss, broadband stripline-to-microstrip transition.

(57) In a flat antenna incorporating one or more low-noise amplifier circuits onto a power divider network, a stripline-to-microstrip transition is provided. The amplifier circuit (100) is mounted vertically on a block (110) between a ground plane (10) and the radiator level (30), so that, in the transition, the electric field of the stripline power divider is rotated 90° to the microstrip mode. A block (110) on which the circuit (100) is mounted forms a connection between the ground plane (10) and the layer of radiating elements (30) which constitutes the other ground plane for the antenna.

FIG. 3



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BACKGROUND OF THE INVENTION

The present invention relates to stripline-to-microstrip transitions, and in particular to such a transition incorporated in a printed-circuit antenna which in turn has incorporated therein a low noise amplifier (LNA) block.

Stripline-to-microstrip transitions are known, for example, in USP 4,862,120 and 4,870,375. USP 4,862,120 discloses a wideband stripline-to-microstrip transition in which the transmission mode of energy passes through a plurality of different transitions of transmission mode, from stripline to microstrip. Different interim modes include quasi-coax, a transitional mode, a double slot mode, and coplanar waveguide. This sequence of transitions eventually changes the stripline mode electric field pattern, which extends in two directions from the stripline itself, to a microstrip mode electric field pattern, which extends in a single direction from the microstrip. However, the transition structure in this patent is somewhat complicated.

USP 4,870,375 discloses a disconnectable microstrip-to-stripline transition, in which a phased array antenna contains a plurality of chassis, each including four antenna elements, each element having associated therewith operating electronics which are implemented in a monolithic microwave integrated circuit (MMIC) approach. The transition is provided in removable form to enable disconnection of a module between an antenna distribution circuit and a beamformer distribution circuit. In the transition, one low noise amplifier is associated with one antenna element.

In copending, commonly assigned Application No. 07/210,433, in which one of the named inventors is also an inventor of the present application, a low noise block down converter (LNB) employing MMICs is provided on a power dividing network layer in a printed circuit antenna which may include a stripline power divider network. The disclosure of that application is hereby incorporated herein by reference.

It is desirable to have a broadband stripline-to-microstrip transition between a power dividing network and one or more low-noise amplifier blocks, and to use a mount for the amplifier, if possible, as a connection between the ground plane of the antenna and a radiating element array which constitutes a second ground plane in the antenna.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the invention to provide a broadband microstrip-to-stripline transition in which a low-noise amplifier is mounted on a metal block which forms a low resistance connection between a ground plane and a radiating element array, those two layers forming the ground planes for the stripline power dividing network.

In the inventive transition, the low-noise amplifier is mounted vertically to connect the ground plane and the radiating element layer. The stripline center conductor in the power dividing network layer is separated from the microstrip conductor by approximately 10 mils, with a gold wire connecting the two.

By orienting the LNA mounting block vertically with respect to the power dividing network layer, it is possible to take advantage of the symmetry of the E-field in the stripline. The LNA block is a microstrip circuit, whose field has a vertical orientation. This vertical orientation of the LNA mounting block folds down the E-field generated by the stripline, to yield an E-field oriented in the same way as that generated by microstrip.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a top view of the inventive microstrip-to-waveguide transition in accordance with one embodiment of the invention;
Figure 2 shows a front view of the transition of Figure 1;
Figure 3 is a schematic of a vertical mounting of another view of the stripline-to-microstrip transition of the invention, implemented in a printed circuit antenna;
Figure 4 shows an end view of the vertical mounting of Figure 3;
Figure 5 shows an integrated low noise amplifier schematic;
Figure 6 shows a measurement of performance characteristics of a stripline test fixture without a microstrip circuit;
Figure 7 shows a measurement of the same fixture, but with microstrip transmission structure incorporated therein;
Figure 8 shows return loss and insertion loss without the microstrip mounting block;
Figure 9 shows return loss and insertion loss with the mounting block, but without a microstrip line element; and
Figure 10 shows return loss of the test fixture with the microstrip line terminated in a 50 ohm chip resistor connected to the ground block.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 shows a top view of the inventive microstrip-to-waveguide transition. The stripline center conductor 1 is connected to the low noise amplifier (LNA) circuit 3, which is mounted on an LNA mounting block 2, via a gold ribbon connect 4.

The LNA circuit substrate, which is made of alumina, is 10 mils thick. The stripline center conductor 1 is approximately 212 mils wide in this embodiment, in order to achieve a 50 Ω characteristic impedance, with a ground plane spacing of 160 mils (see Figure 3). An air gap of approximately 5 mils exists between the LNA mounting block 2 and the end of the stripline 1. An air gap of approximately 2 mils exists between the end of the alumina substrate and the end of the stripline 1. The gold ribbon 4, which is approximately 5 mils wide, joins the stripline 1 to the microstrip 6 on the LNA circuit 3 (Figure 2) across the small air gap. In so doing, the ribbon 4 rotates through a 90° angle so that it lies flat on both the stripline center conductor 1 and the microstrip 6.

While Figure 1 shows the ribbon 4 lying flat on the stripline center conductor 1, Figure 2 shows the effect of the 90° rotation, and thus shows the ribbon 4 lying flat on the microstrip 6.

In Figure 3, a printed circuit antenna includes a ground plane 10, a power divider network 20 and a radiating element array 30 comprised of a plurality of radiating elements (not shown). Individual elements of the power divider network 20 feed respective ones of the radiating elements. A low noise amplifier circuit 100, which may for example be a two-stage amplifier, is mounted on a metal block 110 which extends between the ground plane 10 and the radiating element array 30 to provide a low resistance connection. The radiating element array 30 constitutes the second ground plane of the antenna; thus, the metal block 110 extends between the two ground planes. An example of such an amplifier is shown in Figure 5.

Between the power divider network 20 and the microstrip input 140 is a stripline-to-microstrip transition 130. As seen in Figures 1 and 2, a stripline center conductor 150 is provided on either side of the block 100. The conductor 150 is connected to the amplifier circuit 100 by the stripline-to-microstrip transition 130. The center conductor 150 and the microstrip input 140 and output 145 are separated by approximately 10 mils in the illustrated embodiment, and are connected together by a gold bond wire.

The gold bond is necessary because a DC connection, is required on the RF output for biasing purposes, between the amplifier circuit 100 and the stripline conductor 150. Preferably the bond is a ribbon bond, such as that used in microcircuit assembly, wherein the wire is approximately 5 mils wide and 1-2 mils thick. The stripline and microstrip transmission sections are impedance matched. The circuit 100 itself is configured so as to be self-biased, such that a single positive voltage is applied at the output as a bias, and positive and negative voltages are generated from that as necessary. A high electron mobility transistor (HEMT) may be provided at the front end of the circuit to achieve the low noise characteristic.

With the foregoing construction, the vertical metal wall of the carrier block 110 forms a termination of the stripline transmission mode, in which the electric fields are oriented vertically between the two ground planes comprising the ground plane 10 and the radiating element array 30. In the actual transition region, the electric field of the stripline mode is rotated by 90° to the microstrip mode, since the microstrip circuit itself is oriented vertically. Figure 4 shows the relative 90° orientation between the plane of the stripline center conductor 150 and the microstrip circuit more clearly. The vertical orientation of the amplifier circuit 100 with respect to the power divider network makes it possible to take advantage of the symmetry of the electric field in a stripline transmission mode, and avoids the complicated structure of USP 4,862,120. The vertical orientation of the amplifier circuit "folds" the upper portions of the field down, and also "folds" the lower portions of the field up, to yield the microstrip electric field configuration.

As in copending Application No. 07/210,433, in order to have the LNA block mounted on the radiating element array, it is necessary to sacrifice certain ones of the radiating elements which otherwise might be put on the array. Since the elements may be weighted appropriately, the elements to be sacrificed may be selected so as to minimize the effect on performance of the antenna. For example, elements near the center of the antenna may be sacrificed by replacing the power divider elements which would excite them by the LNA block.

Figure 5 is a schematic of one example of an integrated LNA circuit. In this particular example, the first and second stage devices are self-biased, and the single bias voltage is brought in through the RF output port.

Figure 6 shows a measurement of the stripline test fixture containing no microstrip circuit. Figure 6 was provided to obtain a baseline measurement to characterize the return loss and insertion loss of the external RF connectors and a length of stripline between them.

Figure 7 shows the same measurement, but now with a 0.260" length of 50 ohm microstrip transmission line on a 10 mil thick alumina substrate inserted on a carrier block in the middle. The extra loss shown in this measurement arises primarily from the length of the microstrip line, and the two stripline-to-microstrip transitions at either end. After taking the inherent microstrip losses into account, it is found that the transition loss itself is less than 0.1 dB. This result is associated with a return loss of approximately 17 dB.

Figures 8-10 show that the energy in the stripline mode is coupled primarily to a microstrip mode by the transition structure.

While the invention has been described in detail with reference to a preferred embodiment, various modifications within the spirit of the invention will be apparent to those of working skill in this technical field. Accordingly, the invention should be considered as limited only by the scope of the appended claims.

Claims

1. In a printed-circuit antenna comprising a ground plane, a stripline power divider network disposed over said ground plane, a radiating element array disposed over said stripline power divider network, and a low noise amplifier (LNA) block disposed between said ground plane and said radiating element array, a stripline-to-microstrip transition comprising:

a stripline element associated with said power divider network;

a microstrip element, associated with said LNA block, and impedance matched with said stripline element;

means for connecting said stripline element and said microstrip element electrically; and

means for mounting said LNA block vertically between said ground plane and said radiating element array, said mounting means forming a low resistance connection between said ground plane and said radiating element array,

vertical mounting of said LNA block effecting 90° rotation of an electric field generated by said stripline element with respect to an electric field generated by said microstrip element, said mounting means forming a termination wall for said electric field generated by said stripline element.

2. A transition as claimed in claim 1, wherein said stripline element comprises a stripline center conductor, and wherein said connecting means comprise gold bond wire.

3. A transition as claimed in claim 1, wherein said gold bond wire comprises ribbon wire substantially 5 mils wide and 1-2 mils thick.

4. A transition as claimed in claim 2, wherein said stripline center conductor and said microstrip element are separated by approximately 10 mils.

5. A transition as claimed in claim 1, wherein said radiating element array comprises a plurality of radiating elements, and said power divider network comprises a plurality of power divider network elements for feeding respective ones of said radiating elements individually.

6. A transition as claimed in claim 5, wherein said LNA block is placed on said power divider network so as to replace selected ones of said power divider network elements, so that radiating elements otherwise corresponding to said selected ones of said power divider network elements are not excited.

FIG. 1

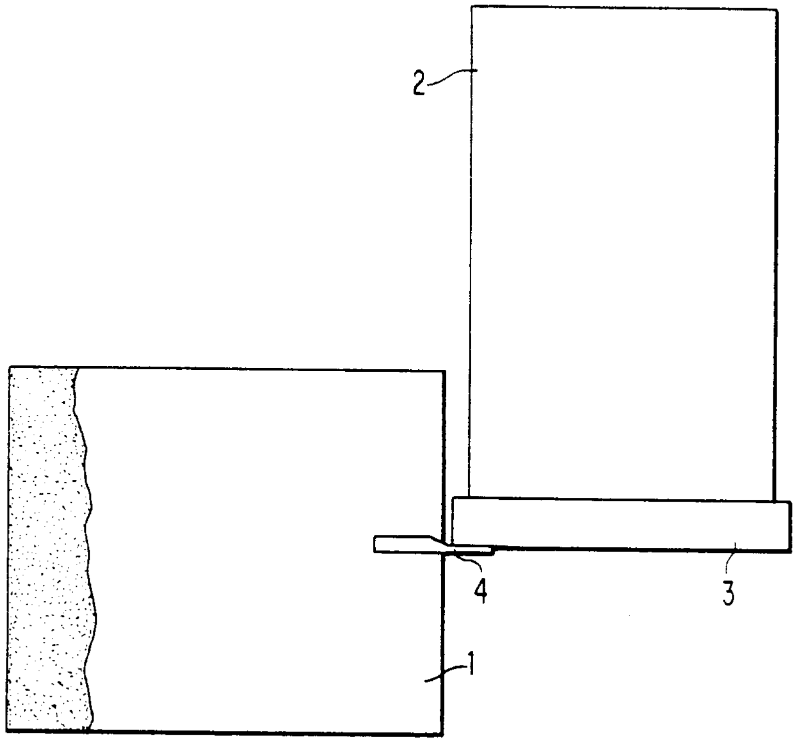


FIG. 2

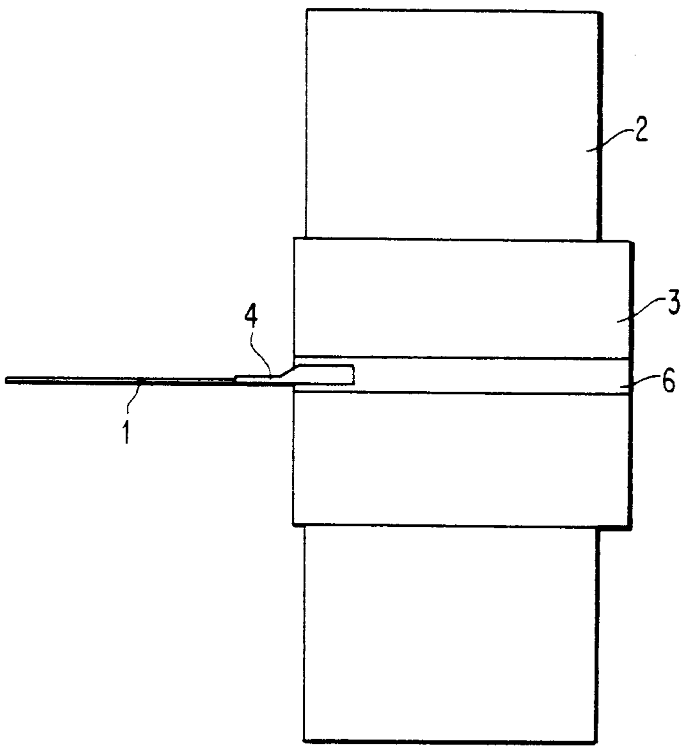


FIG. 3

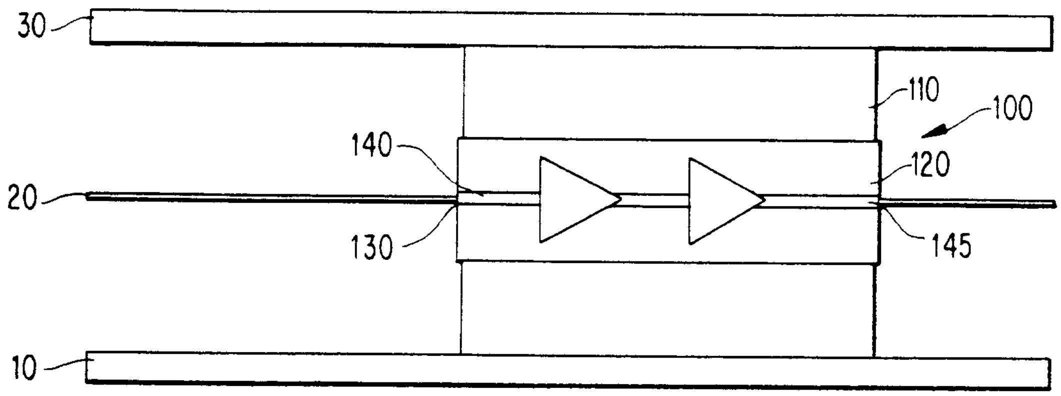


FIG. 4

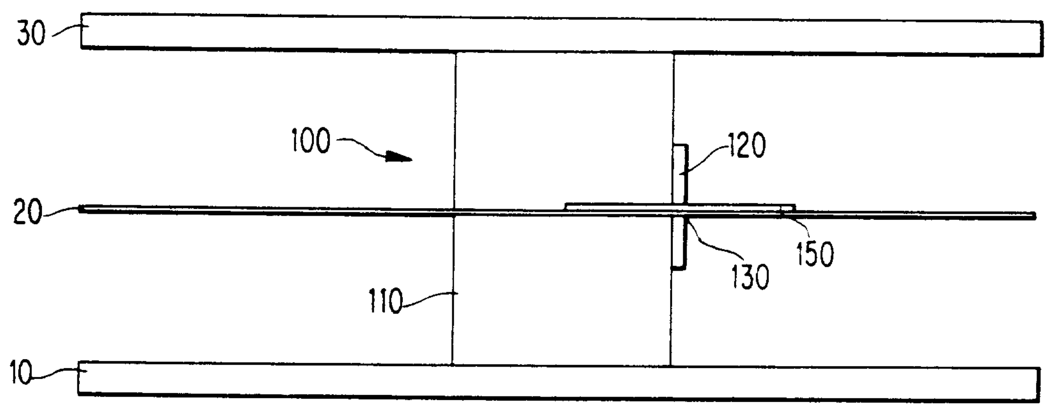


FIG. 5

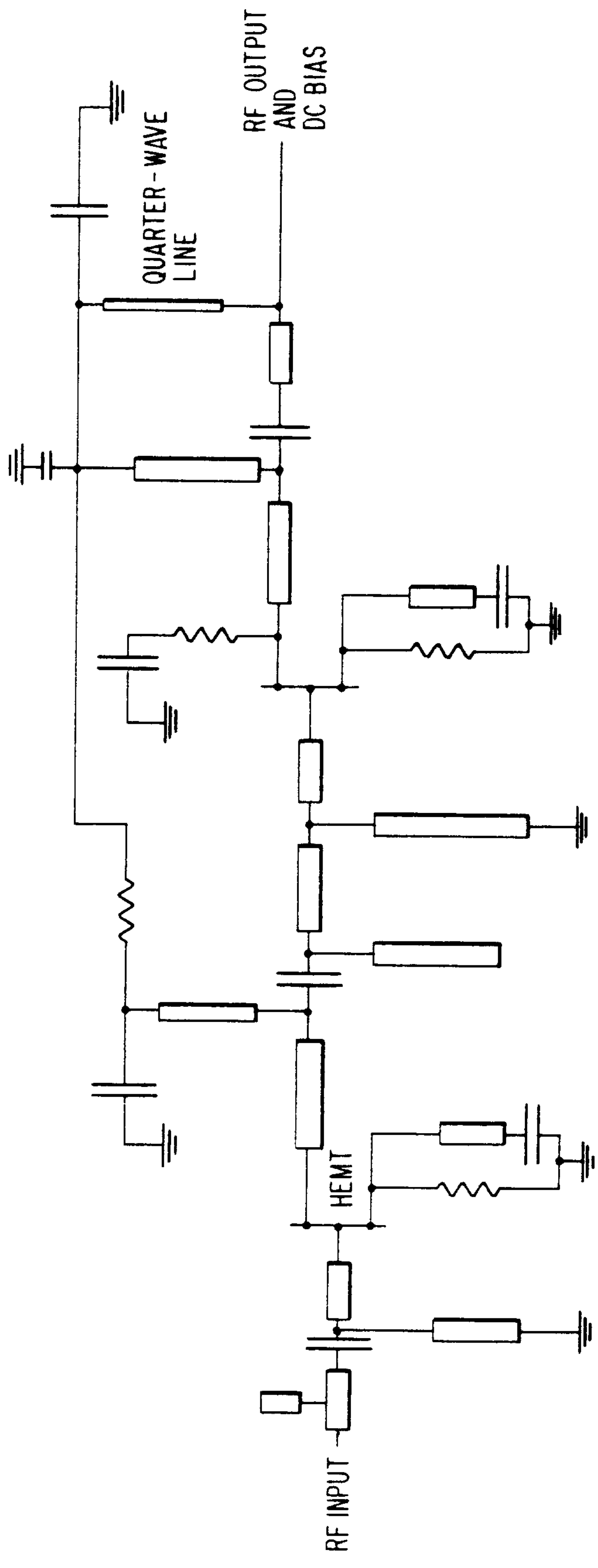


FIG. 6

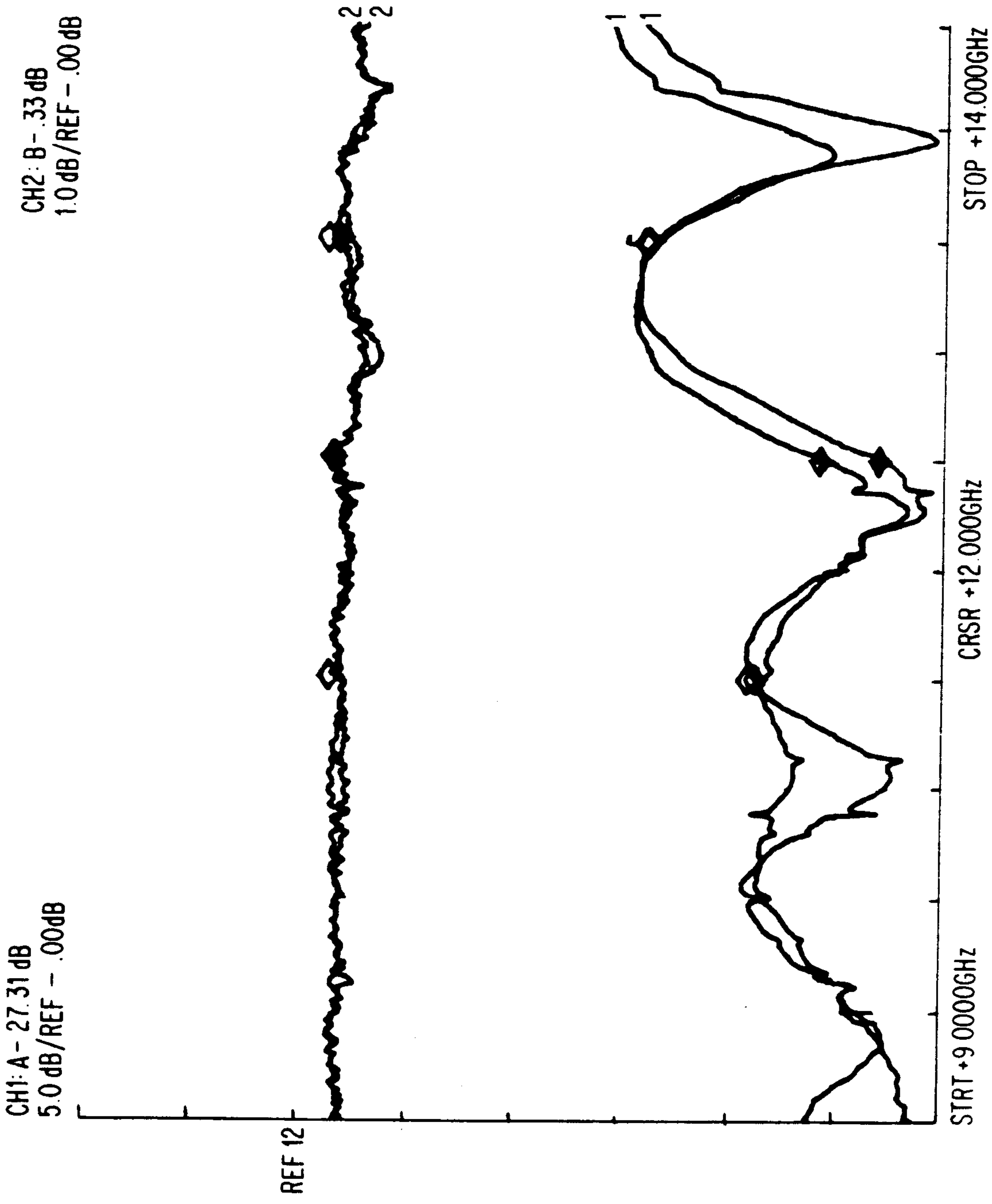

CH1: A - 27.31 dB
5.0 dB/REF - .00dB
CH2: B - .33 dB
1.0 dB/REF - .00dB
REF 12
STRT +9.0000GHz
CRSR +12.000GHz
STOP +14.000GHz
2
2
1
1

FIG. 7

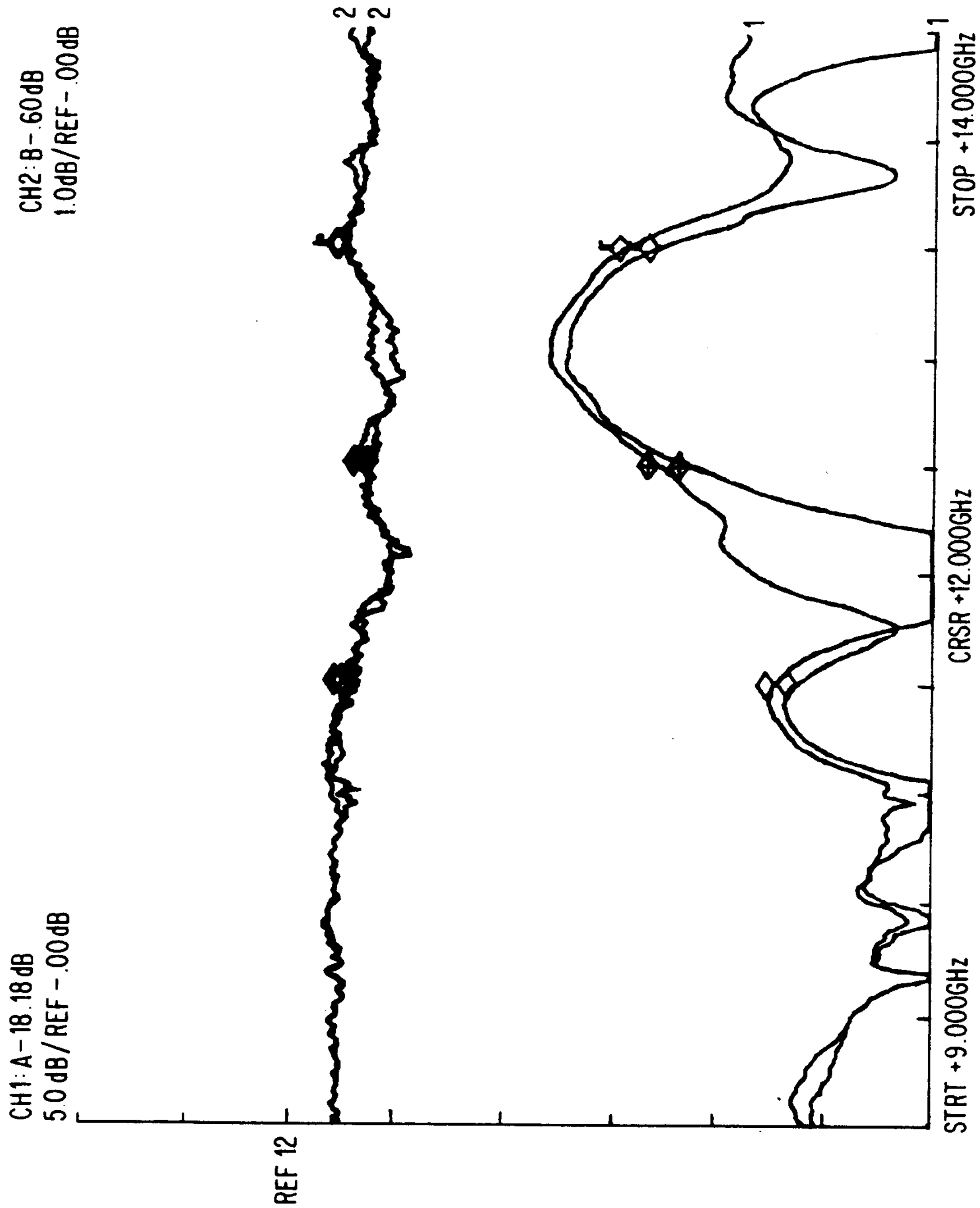

CH1: A-18.18dB
5.0 dB/REF -.00dB
CH2: B -.60dB
1.0dB/REF -.00dB
REF 12
STRT +9.000GHz
CRSR +12.000GHz
STOP +14.000GHz
1
1
2
2

FIG. 8

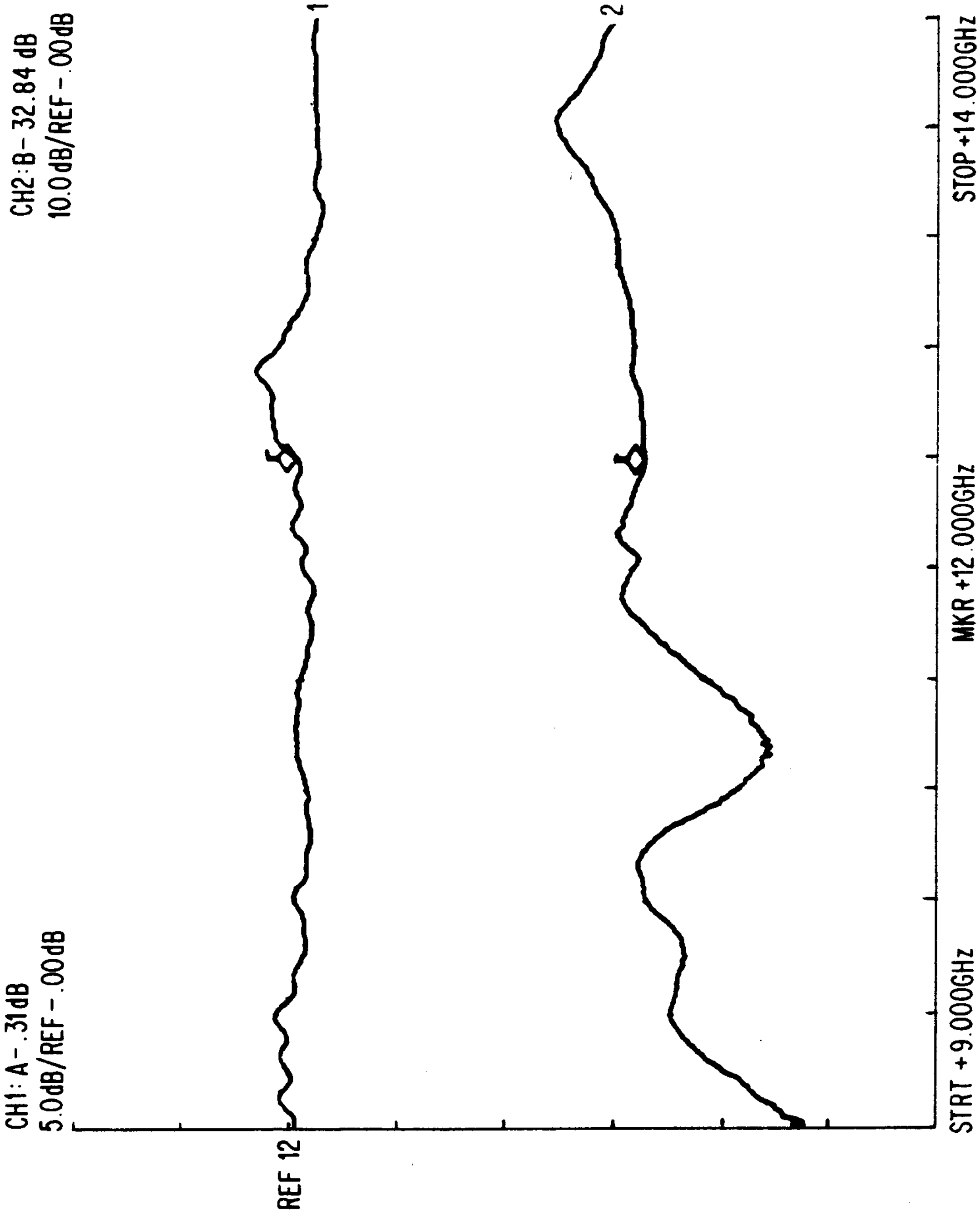
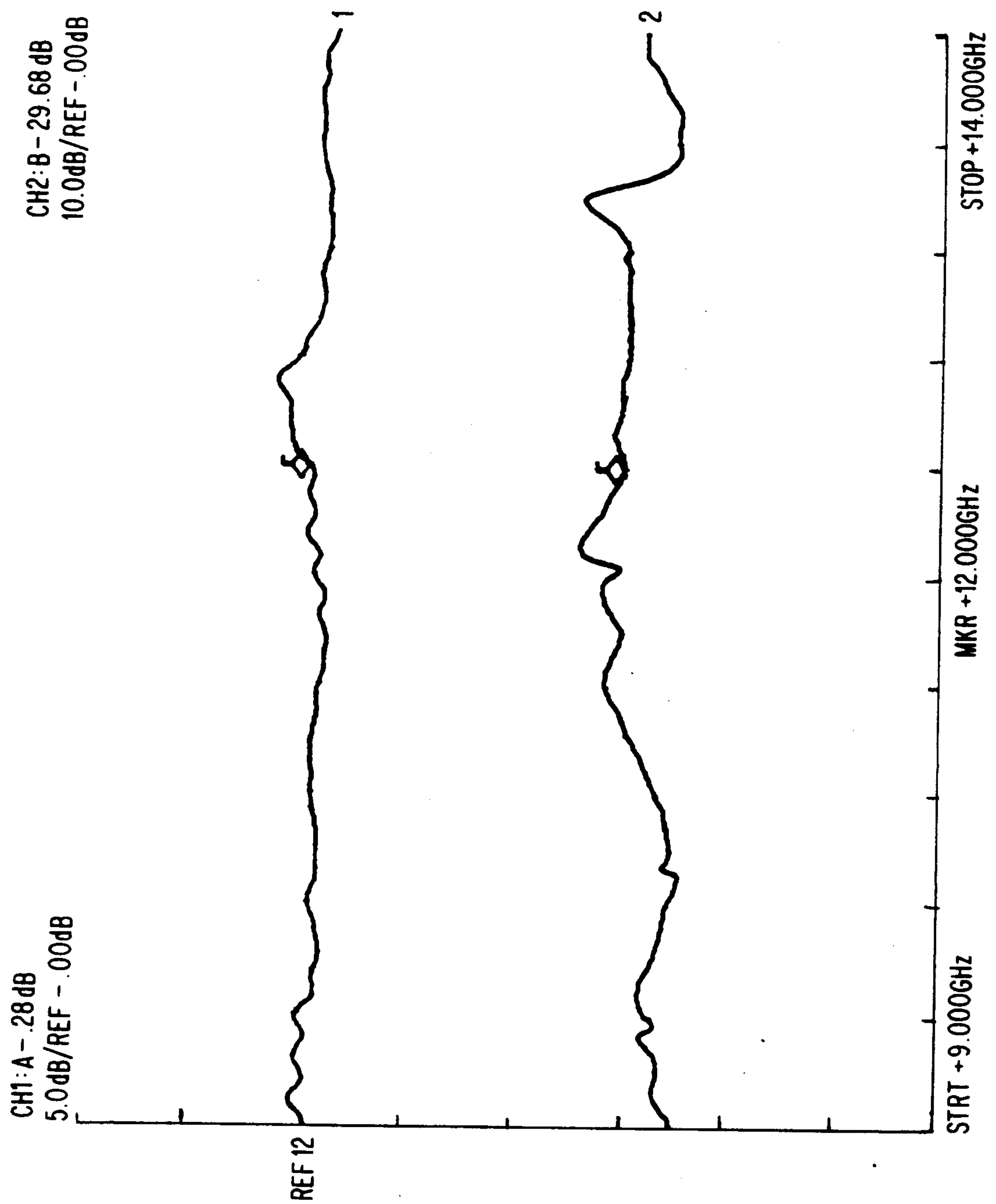

CH1: A - .31dB
5.0dB/REF - .00dB
CH2: B - 32.84 dB
10.0dB/REF - .00dB
REF 12
1
2
STRT +9.000GHz
MKR +12.000GHz
STOP +14.000GHz

FIG. 9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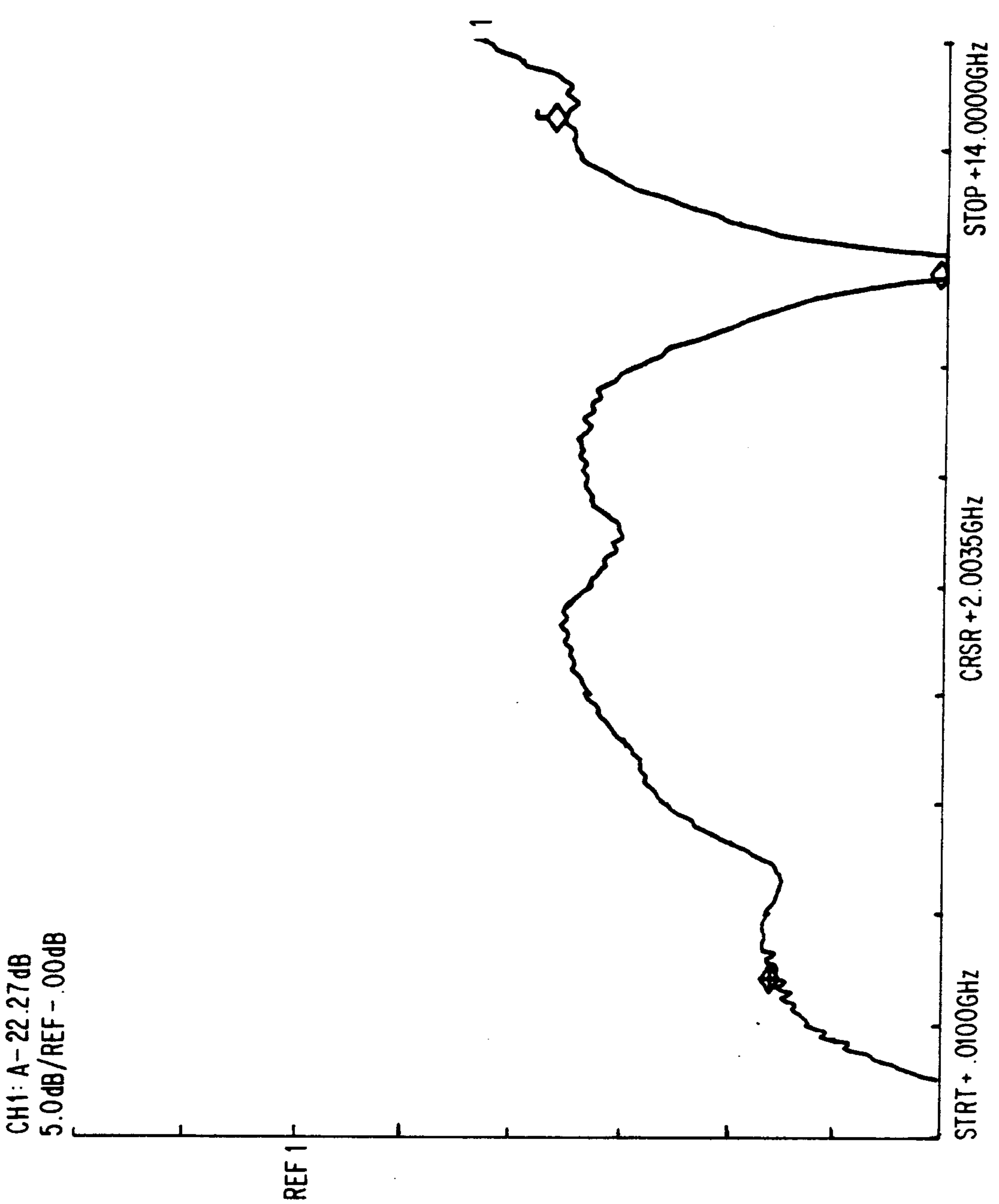
CH2:B-29.68dB
10.0dB/REF-.00dB
1
2
REF 12
STRT +9.000GHz
MKR +12.000GHz
STOP +14.000GHz

FIG. 10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5.0dB/REF-.00dB
REF 1
1
STRT+.0100GHz
CRSR+2.0035GHz
STOP+14.0000GHz

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 8183

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE-A-3 526 046 (ROBERT BOSCH GMBH) * column 2, line 54 - column 3, line 12; figure 1 * ---	1,5	H01P5/08 H01Q21/00
A	EP-A-0 283 396 (THOMSON-CSF) * column 5, line 55 - column 6, line 1 * * column 7, line 18 - line 49; figures 10,16 * ---	1,5	
A	IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION vol. 35, no. 6, June 1987, NEW YORK US pages 728 - 731 D.M. POZAR ET AL. 'An aperture coupled microstrip antenna with a proximity feed on a perpendicular substrate' * page 728, right column, line 3 - line 16; figure 1 * ---	1	
A	1991 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM-DIGEST,Vol.3;June 10-14,1991, Boston,US;IEEE,New York,US,1991 S. NELSON et al.:"Optimum microstrip interconnects" pages 1071-1074 * figure 1 * ---	2,4	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H01P H01Q
A	EP-A-0 195 520 (TEKTRONIX INC) * page 5, line 12 - page 6, line 23; figures 1,2 * -----	3	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 APRIL 1993	DEN OTTER A.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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L : document cited for other reasons

& : member of the same patent family, corresponding document