A SIMPLE ELECTRIC NEAR FIELD PROBE FOR MICROWAVE CIRCUIT DIAGNOSTICS

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ABSTRACT

An electric field probe applicable to the 1 - 20 GHz band has been developed, using miniaturized semirigid coaxial cable. It is shown that the probe is well suited for the diagnostic of the microwave circuits. The field probe has very small dimensions and it does not need to be connected to the operating circuit under test, therefore the circuits properties nearly are not disturbed by the probe. This simple, stable and cheap field probe is very useful for assisting the design of microwave circuits, antenna diagnostics and testing products in industry. As an example, the field distribution in a 2.4 GHz hybrid power amplifier is measured and the result is analyzed in this paper.

INTRODUCTION

Today's highly complex microwave components and circuits have generated the need for a probe for measurements inside the operating circuit. Some miniaturized magnetic field probes have been reported for measurements in high-frequency planar circuits[1, 2]. However, such probes appear to be incompatible to strong radiating circuits, for example antennas and circuits with smaller dielectric constant substrates. An electro-optical probing system provides a very wide bandwidth and good resolution [3], but such a system is normally complicated, expensive, and applicable only to special substrates. A simple and practical probe using the inner conductor of a coaxial cable has been applied to measure the permittivity ε of dielectric materials [4] and the investigation of field distributions [5]. In this paper the probe construction and measurements on a planar patch antenna, a meander line and a 2.4 GHz hybrid power amplifier are described. The measurements demonstrate that this probe can be applied to measure not only the near field of a simple passive circuit but also the near field of a complicated active circuit.

THE PROBE

In the high frequency regime the dimensions of circuits are very small. In order to accurately measure the amplitude and phase of fields at points inside a circuit, a field probe must be as small as possible, so that the perturbation of the operating circuits by the probe can be ignored approximately.

The electric field probe is very simply constructed from a semirigid coaxial cable. Several such probes were fabricated with different inner and outer sizes, which can be used for different frequencies and different objects. The smallest probe consists of a miniature coaxial line with 508 μm outer diameter and 120 μm inner conductor extending 300 μm beyond the outer conducting shield, as shown in figure 1.

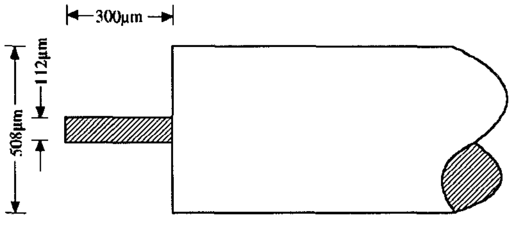

Fig. 1. Coaxial electric field probe.

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This field probe is in principle a capacitive probe. In an electromagnetic field an electric current is induced in a capacitor in the form of

$$i = C\frac{du(t)}{dt},$$

where $u(t) = AE(t),$

$$\frac{du(t)}{dt} = A\frac{dE(t)}{dt},$$

and let $E(t) = \overline{E}f(t),$

with $|f(t)| \le 1,$

$$\frac{dE}{dt} = \overline{E}\frac{df(t)}{dt},$$

so that $i = CA\overline{E}\frac{df(t)}{dt},$

where $\overline{E}$ is the magnitude of the electric field strength of magnitude E, C is the value of the capacitance and A is a system constant. For the coaxial cable probe the induced current mainly is induced by the z-component of the electric field. It is valid that:

$$\vec{E} = \vec{E}_x + \vec{E}_y + \vec{E}_z,$$

$$|\vec{E}_z| >> |\vec{E}_x|, \quad |\vec{E}_z| >> |\vec{E}_y|.$$

The expression of the probe current induced by the electric field E then approximately is given by:

$$i \approx CA|\vec{E}_z|\frac{df(t)}{dt}.$$

From this expression it can be seen that the current of the probe to a first approximation is proportional to the vertical component of the electromagnetic field.

MEASUREMENTS

The measurement system, which is used here, is described in[2].

(1) MEASUREMENT OF A MICROSTRIP PATCH ANTENNA

The first structure under investigation is a microstrip patch antenna shown in figure 2(a).

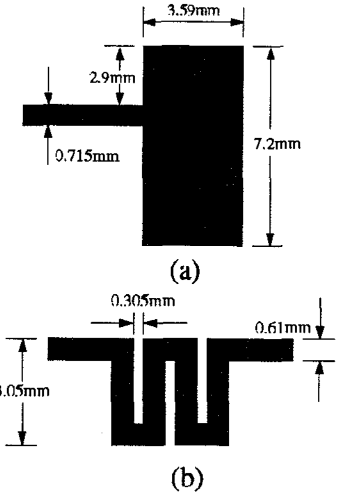


Fig.2. The structures of (a) a patch antenna and (b) a meander line.

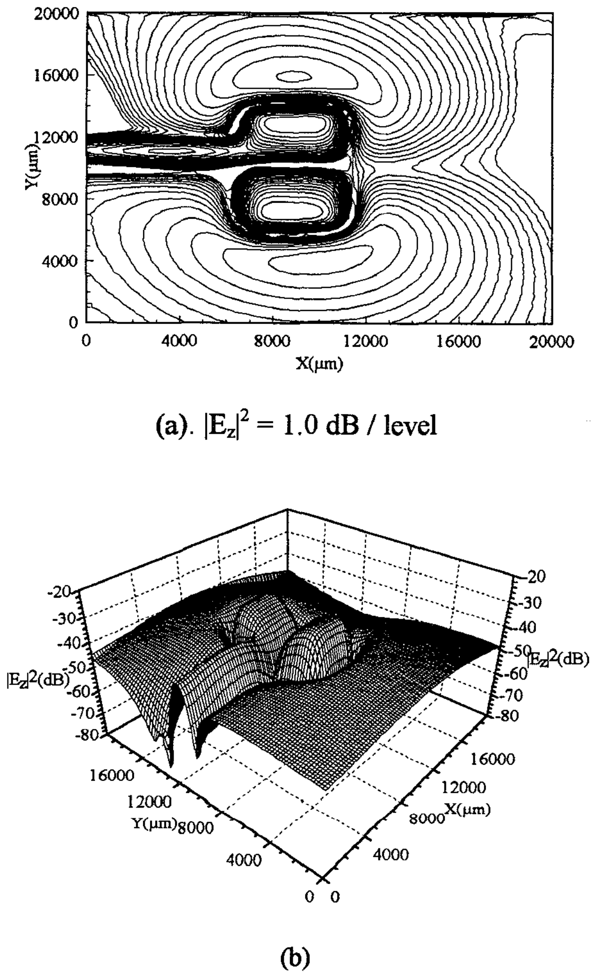
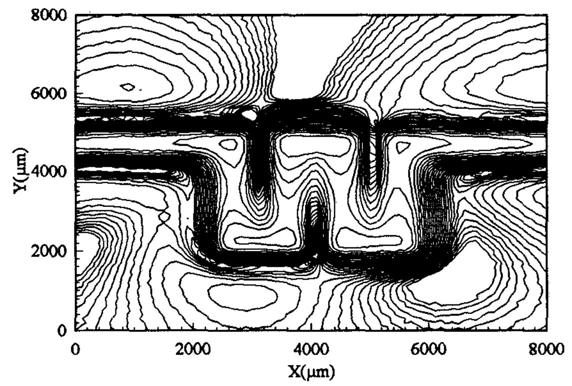
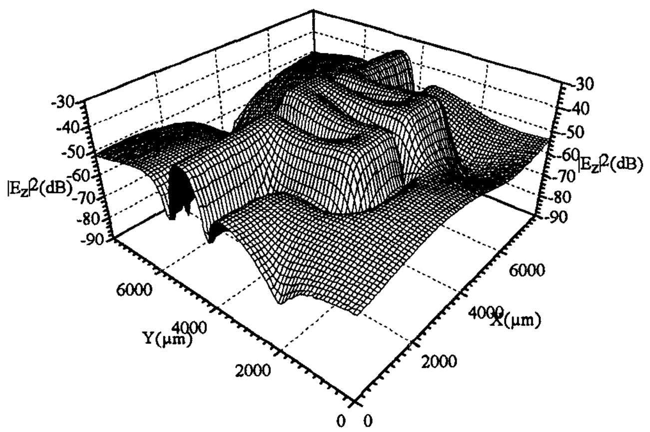


Fig.3. $|E_z|^2$ distribution for a 13.12 GHz patch antenna.

The microstrip patch antenna is fed by a microstrip line in the same plane. The substrate thickness is h = 790 µm and the relative permittivity is ε_r=2.2. The measurement has been taken over a region of 20 x 20 mm^2. Scanning steps of 200 µm in the x- and y-direction are employed, so that 10000 field values are measured in each measurement cycle. The probe is placed in a height of 100 µm above the substrate for this measurement. In figure 3(a) a three dimensional presentation of the field is shown, where the measured signal S_{21} from the network analyzer is between -20 and -80 dB. The boundary of the conductor is shown in the contour picture figure 3(b) by broken lines. An asymmetrical radiation field of the antenna in Y-direction is observed. This is due to the error of the soft substrate or the error of the fabrication.



(a). $|E_z|^2$ = 1.0 dB / level



(b)

Fig.4. $|E_z|^2$ distribution for a microstrip meander line at 11.4 GHz.

(2) MEASUREMENT OF A MEANDER LINE

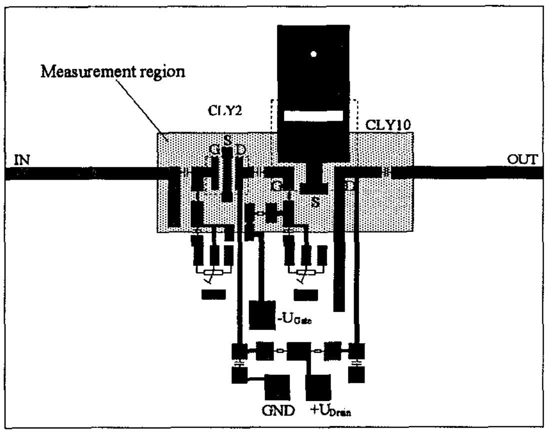
The next example is a meander line structure. It consists of a section of closely coupled bends and transmission lines on a ceramic substrate shown in figure 2(b). The substrate height is 635 µm and the relative permittivity is ε_r = 9.8. The measurement is taken over a region of 8 x 8 mm^2. Scanning steps of 100 µm in the x- and y-direction are employed. The probe is placed in a height of 50 µm. The boundary of the conductor is shown in the contour picture figure 4(b) by the broken line. A comparison between the measured and the calculated results (not shown here) shows that the overall agreement is good.

(3) MEASUREMENT OF A HYBRID 2.4 GHZ POWER AMPLIFIER

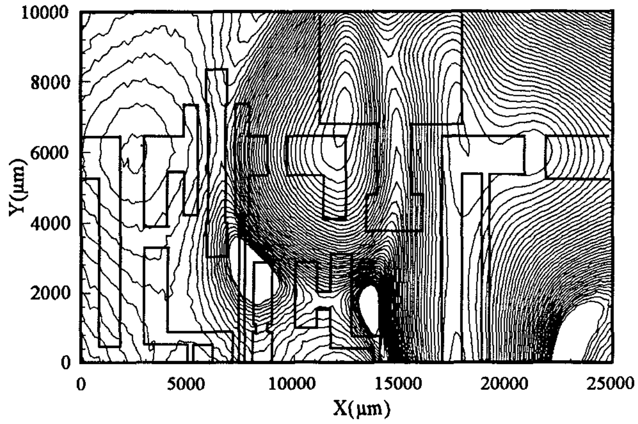
The last example is a hybrid power amplifier (1 W) at 2.4 GHz. This is a two stage power amplifier with 20 dB gain, which is constructed on RT Duroid (ε_r = 2.2, h = 635µm) substrate. The layout of the amplifier is shown in figure 5(a). The first and second stages consist of two GaAs FET CLY2 and CLY10 from Siemens AG. The first stage and the second stage have about 13dB and 7dB gain respectively. The measured vertical electric field distribution in a position 2300 µm above the amplifier is shown in figure 5(b,c). The maximum electric fields are measured at the output ports of the two transistors. There are also two local maximum at the input and output capacitors. This is due to the coupling effect of the capacitor. The minimum fields are measured near the DC power supply. From the field distribution the power transmission of the RF-part and the good isolation of the dc-part from RF can be clearly identified. From the measurement it can be seen that the electric field probe is a valuable technique for microwave circuit diagnostics and that is capable of providing essential physical insight into the problem areas of the designed circuits.

CONCLUSIONS

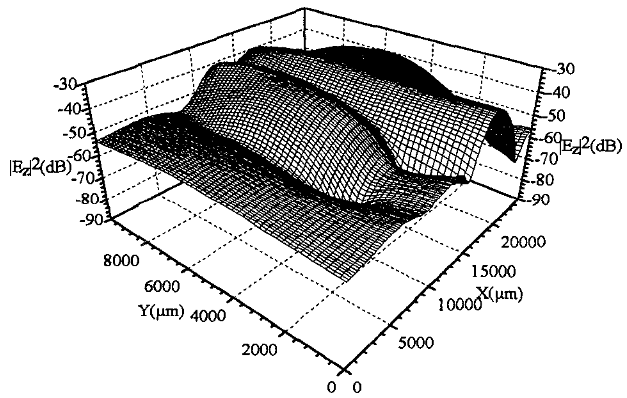
A simple coaxial electric field probe for measuring the field distribution in high frequency circuits has been presented. Various measurement examples are given to demonstrate that such near field probes can



(a)



(b)



(c)

Fig.5. Two stage power amplifier at 2.4 GHz (a) layout, (b, c) $|E_z|^2$ distribution.

be applied not only to simple passive circuit analysis but also to the analysis of complex circuits. This probe is useful for amplitude and phase measurements of the electric fields at interior points of planar microwave circuits and helps in the design and manufacturing process of microstrip and other printed antennas.

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