Use of H-field and E-field micro-probes at IC level

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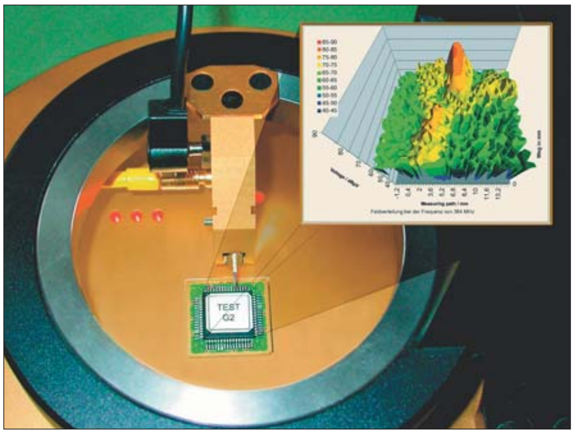
This article describes results of near-field examinations that were carried out with probes of 150 μm diameter. The characteristics and resolutions of the probes are investigated more closely through measurements on common mode and differential mode models. A sample IC is used to compare direct current and near-field measurements.



■ Disturbances emitted by ICs are mainly due to IC near fields. The identification of these fields would greatly benefit IC development. Near-field probes are usually used for this purpose. The smallest available near-field probes which have been developed to examine electronic modules are presently around 1 to 2 mm in size. This resolution, however, is not sufficient to examine ICs. ICs have much finer conducting networks. Only micro-probes in the μm range can be used to examine ICs in terms of pin, bonding wire, lead frame or chip. The following paper presents results from examinations that were carried out with probes of 150 μm diameter. The characteristics and resolutions of these probes are investigated more closely through measurements on common mode and differential mode models. A sample IC is used to compare direct current and near field measurements.

Practical experience with EMC measurements has shown that the electric field is also important alongside the magnetic field. Field-specific probes allow the designer to detect and thus analyse the fields separately. The ICRH S and ICRH H probes are used for the H-field in these near-field examinations. The measuring coil of the H-field probes has an inner diameter of approx. 150 μm and an outer diameter of approx. 250 μm. The coil's orientation is the distinguishing feature between both probes: ICRH S is vertical and ICRH-H is horizontal. Both probes are shielded against E-field. The E-field attenuation is approx. 20 dB. The voltage induced in the coil is amplified by 30 dB within the probe. The measuring range is between 16 kHz and 3 GHz. The E-field is measured using the ICRE probe with a probe head size of 150 μm x 35 μm. The E-field probe works with the same amplifier and measuring range as the H-field probes (www.langer-emv.de/produkte/IC-Nahfeldsonden.htm).

The ICRH S, ICRH H and ICRE field probes are used to measure the near field first on a round conductor and then on two round twin conductors at various heights above the conductors. The transmission factor can be determined on the round conductor. These measurements are relative to the horizontal and the vertical distance as well as to the current that flows through the round conductor. The probes are guided by an IC S 103 scanner.

The transmission factors in the frequency range between 16 kHz and 3 GHz are determined on the round conductor. The measurement is based on the following parameters: the round conductor has a diameter of 25 μm and a termination of 50 Ω. The probe coil's low end is adjusted to a height of 20 μm above the round conductor. The round conductor is supplied with 107 dBμV (0 dBm) via the tracking generator of the R3132 spectrum analyzer. All further measurements on the round and twin conductors are carried out at this supply. Increments of 0.05 mm are chosen to measure the transfer characteristics. The ICRH S, ICRH H und ICRE characteristics are shown at www.langer-emv.de/produkte/IC-Nahfeldsonden.htm. Figure 1 shows the H-field expansion: the induced voltage as a function of the lateral distance to the round conductor. The fields of two parallel conductors (twin conductors) are scanned to analyse the resolution and behaviour of the probes more closely. The conductors are operated in differential or common mode and their distance is varied. In addition, the field is examined as a function of the vertical measuring position. The set-up and its variations are shown in the diagram in figure 2a. The probe detects measurable differences between the fields of the conductors as a function of the height.

Figure 2b shows the modification of the distance between the twin conductors carrying differential-mode currents at a probe distance of 20 μm above the twin conductors. The distance set between the conductors can be easily read from the measured peaks. Each round conductor remains clearly identifiable even at a distance of 0.1 mm between the twin conductors. If the height of the probe above the twin conductors is also considered, it can be seen that

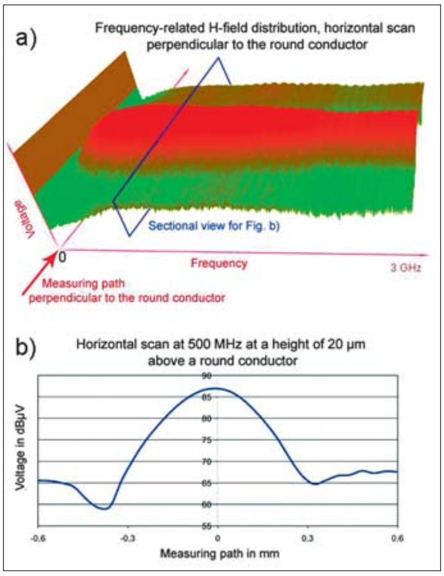


Figure 1. Field distribution on round conductor

the round conductors can still be distinguished with increasing height, figure 2d. This measuring set-up corresponds to loops on the DIE of ICs.

Figure 2c shows the modification of the distance between the twin conductors carrying common-mode currents at a probe height of 20 µm. The peak can again be used as an indicator for the set distance. Both magnetic fields merge into one if the distance between the twin conductors decreases to less than 0.3 mm. If the height of the probe above the twin conductors is also considered, it can be seen that a distinction is no longer possible with the twin conductors spaced at 0.6 mm as of a height of 0.2 mm, figure 2d. An application-oriented wiring is chosen for the measurements on the IC (64-pin QFP). The E-field in the area of the pins 53 to 59 is measured with the ICRE probe. The E-field is not detectable in the frequency range from 10 to 1000 MHz. It thus has no effect on the H-field measurement in this example.

Measurements with ICRH S above pins 53 to 59 show that the spectra measured reach a maximum above the V_{DD} pin. A contraction is visible between V_{DD} and V_{SS}, figure 3a. The differential-mode measurements on the twin conductors suggest that the disturbance travels from the V_{DD} pin to the V_{SS} pin via the blocking capacitor and thus forms a differential-mode system. The stray field is responsible for the field configuration above the other pins. The current is measured on the V_{DD} pin so that the results of the H-field measurements can be compared. The current has to be measured at a very low impedance to avoid any measurement degrading. The ammeter probe 622 is used because it has an internal resistance of 1 Ω and is thus suitable for measurements on voltage supply pins (data sheet: www.langer-emv.de/produkte/prod_hf.htm).

The direct measurement of the current produces a wide spectrum; dark blue curve in figure 3b. A relationship is clearly visible by comparing the spectra of the current and the field measurements. The H-field distribution above the chip is determined with ICRH-H in an additional surface measurement with the ICS 103 scanner. Figure 4 is a three-dimensional representation of the H-field distribution at 384 MHz. This 3D diagram shows the field strength as a function of the location. A large area of high field strengths can be seen in the top right. The connections to the supply pins investigated are also located there. Lower field strengths in the form of lower induced voltages are present because the distance to the bonding wires is larger than in the measurements directly above the pins. A light red and an orange range of highest field strengths are visible in the V_{DD} pin area. The yellow ranges represent the field above the lines to and from the other supply pins. The measurements of the current spectra on the other supply pins confirm that the field spectra above the IC correlate with those of the current. These H-field measurements thus allow the designer to trace the current paths on the IC in the near field.

The measurements on simulated neighbouring pins in the form of twin conductors show that the expected fields can be evaluated as E- and H-fields. Measurements in the near-field range can be performed quickly and with reproducible positions. Structures of varying fineness can be dissolved taking such parameters as distance (lateral/height), step size and applied field strengths into consideration and measured separately according to the type of field. Resolutions in the 100 µm range give a precise insight in the distribution and strengths of fields and their potential disturbance emissions.

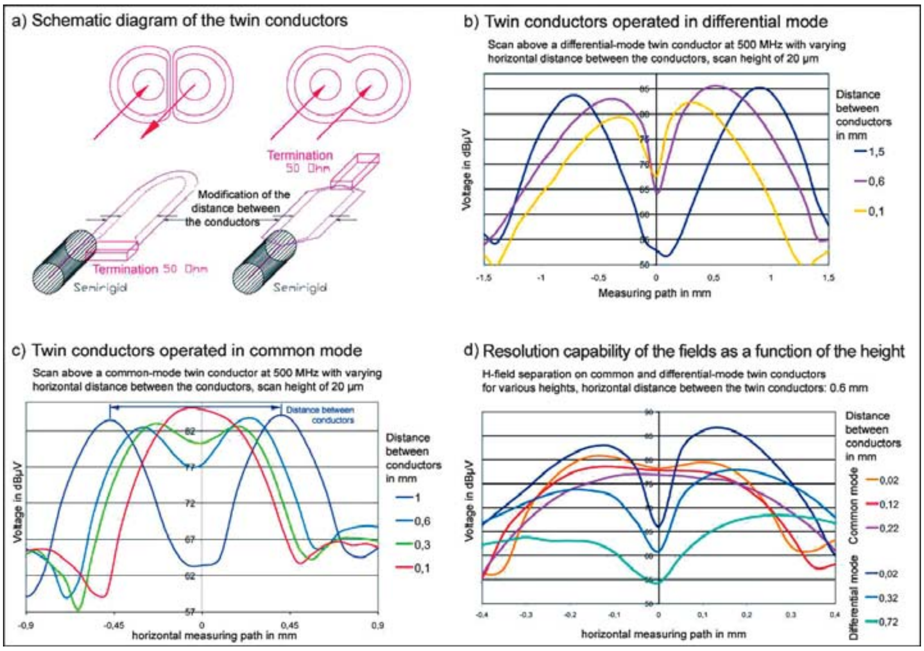


Figure 2. Field distribution on twin conductors

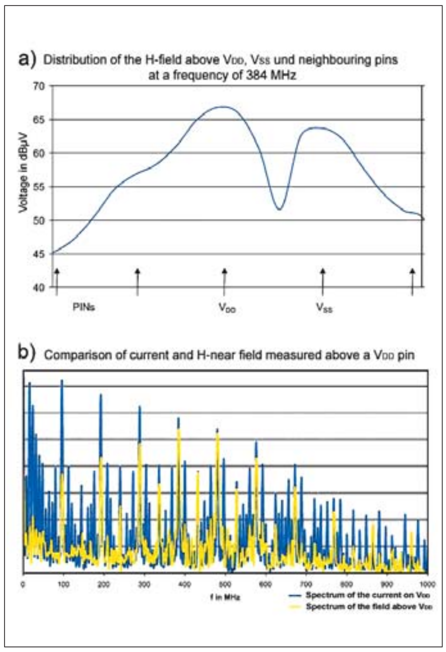


Figure 3. Results on supply pins

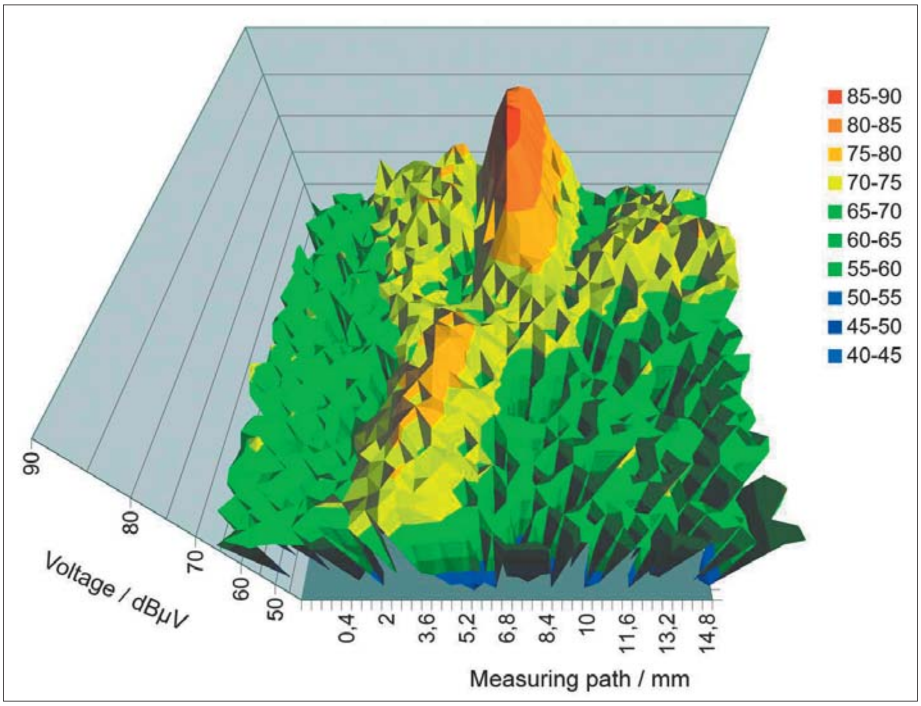


Figure 4. 3D H-field distribution above IC at f = 384 MHz

Current and field measurement matches can be determined on the IC. The spectrum and sphere of action can be extracted as a result of these measurements. The supply pin example shows that a distinction between individual pins can be made based on the field orientation. Important IC development tools are thus provided. Both the E-field and the H-field can be determined separately above and on small structures such as open DIEs by micro-probes. The current paths of the IC can be traced through H-field measurements in the near field.

Measuring IC samples at different stages or development allows the designer to analyse and determine how his modifications affect the IC in the near-field range. Conclusions can thus be drawn and continuous modifications made during the development process. These probes open up new possibilities in the field of IC technology. ■