ICIC Express Letters
Part B: Applications
Volume **9**, Number **1**, January **2018**
ICIC International ©2018 ISSN 2185-2766
pp. 37–45

NOVEL TESTING METHOD FOR SIGNAL COUPLING AND DISCONTINUED NOISE BY NEAR-FIELD MEASUREMENT SYSTEM

Ren-Fang Hsu[1], Meng-Hua Tu[1], Sung-Mao Wu[1,*], Chun-Sen Wu[1]
Yung-Mao Cheng[1], Chia-Lin Chen[2], Wei-Jen Chen[2]
Cheng-Fu Yang[1] and Cheng-Yi Chen[3,*]

[1]Department of Electrical Engineering
National University of Kaohsiung
700, Kaohsiung University Rd., Nanzih District, Kaohsiung 811, Taiwan
*Corresponding author: sungmao@nuk.edu.tw

[2]Medical Devices and Opto-Electronics Equipment Department
Metal Industries Research and Development Centre
Kaohsiung 821, Taiwan

[3]Department of Electrical Engineering
Cheng Shiu University
No. 840, Chengcing Rd., Niaosong Dist., Kaohsiung City 83347, Taiwan
*Corresponding author: k0464@gcloud.csu.edu.tw

Received July 2017; accepted October 2017

Abstract. *In this paper, we would investigate a novel near-field system for microwave measurement. Through the measurement by near-field system, circuit's electromagnetic radiation pattern could be well known. The electromagnetic radiation pattern would show the hot point where weak position was and designers could design the circuit in better condition. Finally, we would show that the time domain electromagnetic radiation patterns would have the differential crosstalk and the result of signal discontinued noise measurement.*
Keywords: Near-field, Coupling, Discontinued noise, Domain reflectometer

1. **Introduction.** Consumer electrical products with high-speed design and high frequency design have continuously come out year by year and the transmitted speed of those products also rises continuously. For example, speed of Double Data Rate (DDR) Memory products has 16 times growing up from 200Mbps to 3200Mbps (DDR3 and DDR4) and Universal Serial Bus (USB) also have 10 times growing up from 480Mbps (USB 2.0) to 5Gbps (USB 3.0). The design of off-chip signaling will face lots of difficulties, such as signal distortion by multi-reflection, timing delay mismatch and radiated emission due to high frequency harmonics. In addition to the difficulties of design process, how to carry out the efficient and reliable tests has become a serious issue for system designers.

The concepts of near-field testing/measurement come from IEC 61967-3:2014 [1], which provides a test procedure which defines an evaluation method for the near electric, magnetic or electromagnetic field components at or near the surface of an integrated circuit (IC) [2]. After many years of development and independent industry evaluation, near-field antenna testing has come of age and is the preferred approach for characterizing antennas. For example, Shen et al. used the finite-difference time-domain (FDTD) analysis software to calculate the electrical field of MtimesN points in a fictitious plane at different times just like the actual PNF sampling in the time domain (TD) [3]. This diagnostic procedure is intended for IC architectural analysis such as floor planning and power distribution optimization.

In the past, Escotte et al. investigated an algorithm used for noise parameter fitting on the accuracy of the microwave noise parameter measurements [4]. They compared five different commonly used algorithms by a statistical analysis including instrument accuracy specifications. Hayward found that Agilent Technologies PNA-X Option 029 can provide capability for noise figure measurements in a 50Ohm environment. He described a method for extending the analyzer's capability to obtain measurements for noise parameter extraction [5]. Belostotski and Haslett compared the performance of source-tuner noise-parameter extraction methods used to measure noise parameters of low-noise amplifiers that have very low (1dB) noise figures [6]. The methods were known as the Cold method and the modified Y-factor method (or Hot-Cold method). IEC 61967-3:2014 also describes using loop coil or antenna to detect leaking magnetic field from the technologies of Device under Test (DUT) or Equipment under Test (EUT). Advantages of the investigated testing method have the figure merits of debug flexibility and easily controlling. In this study, as shown in Figure 1, based on these advantages, a novel signal integrity measurement method had been presented to measure signal coupling for differential signaling and discontinued noise from impedance mismatch by near-field testing instrument EM-ISight presented by Aprel, Inc. which can combine software and hardware well and efficiently for SI/PI measurement study [7]. This method would provide higher testing flexibility than that of traditional contacting measurement due to no requirements of testing points on DUT system. The technology investigated could also enhance more design flexibility for PKG/PCB layout area and decrease related cost.

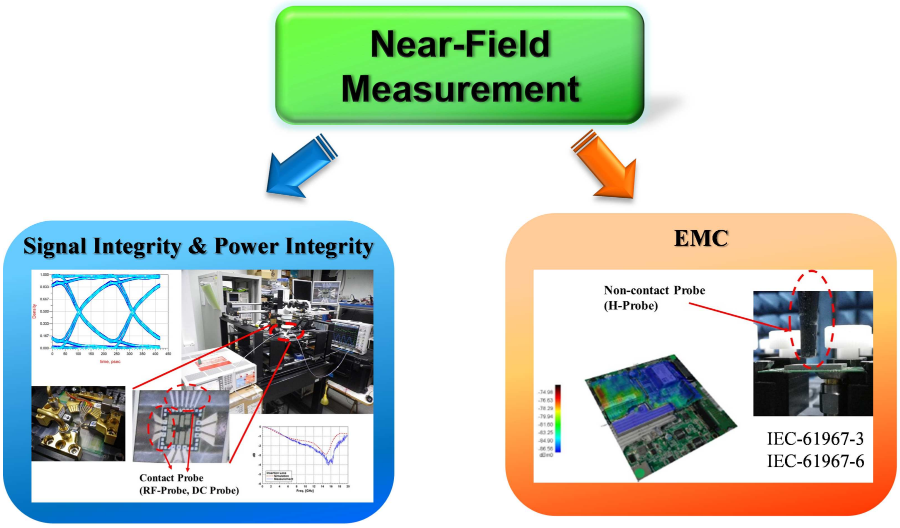


FIGURE 1. Something the near-field measurement can do

2. **Measurement System.** As shown in Table 1, EM-ISight equipment has a great deal of features, for that it has many applications and it can be used to carry out the near-field testing/measurement. As table shows, the EM-ISight equipment has a high moving resolution of 25μm, shifting in the directions of three axes, high frequency of 6GHz probe, -135dBm noise floor at 1GHz and dynamic touch detection function with 5μm at Z-axis. The traditional EMI/EMC measurement instrument and related equipment are shown in Figure 2. Signal transmits from DUT or EUT and radiate to H-field probe with 6GHz bandwidth. A Low Noise Amplifier (LNA) can amplify a very low-power signal without significantly degrading its signal-to-noise ratio. Then, the signals can be enlarged by LNA with 30dB gain and the signals can be received and analyzed by spectrum analyzer.

Table 1. Features of EM-ISight equipment

Feature	Performance
Frequency Range	10kHz-6GHz
Noise Floor	−135dBm@1GHz
Probe Option	H-field probe, 10kHz-6GHz
Scan Volumes (X × Y × Z)	300mm × 300mm × 300mm
Step Size & Surface Detection	Minimum step: 25μm Dynamic touch detection: @5μm in Z

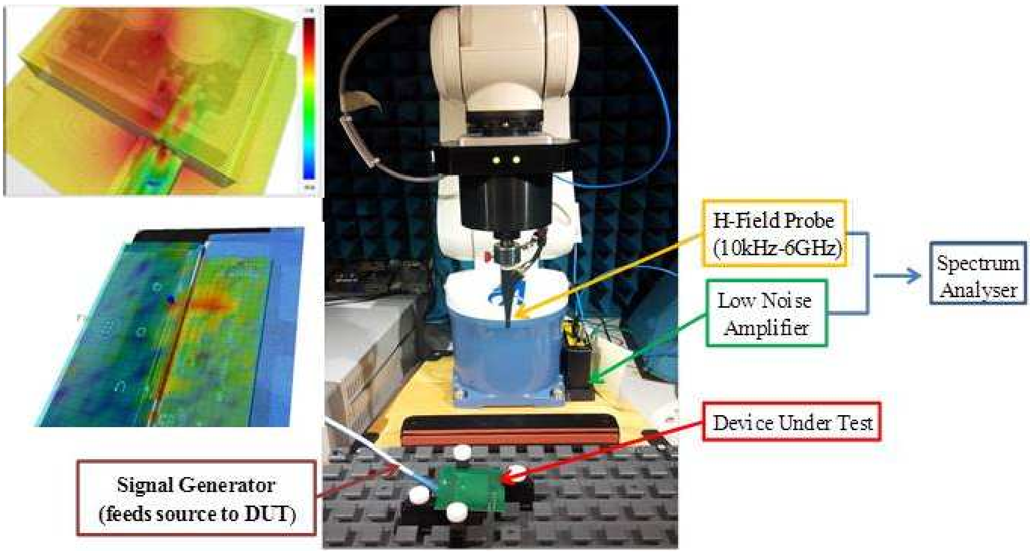


Figure 2. Measurement system: EM-ISight

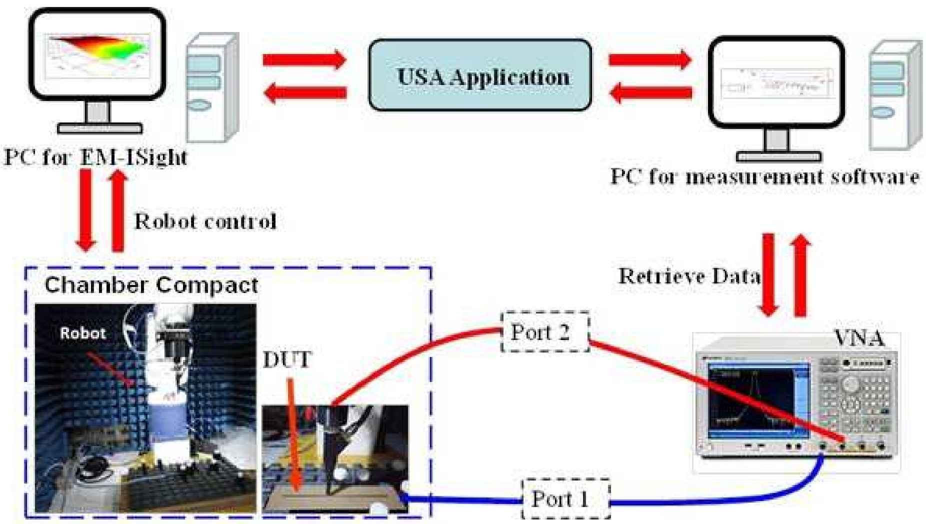


Figure 3. Block diagram of measurement system

Designers can know the hot spots from post-processing via the provided software from instrument vendor to analyze the designed circuit and debug.

This study presented a novel testing method about signal integrity by near-field testing instrument and circuit simulator for advanced post-processing. Figure 3 shows the block diagram of the integrity measurement system for the signal testing. Port 1 of Vector Network Analyzer (VNA) was designed to have a 50Ohm termination and that could transfer the output signals to other ports of DUT with avoidable multi-reflection. At the receiver end, loop antenna probe was designed to receive radiating emission into VNA port 2, for that the S-parameters were obtained. Then, post-processing in circuit simulator Advanced Design System (ADS) with transient simulation results would be carried out to obtain time-domain performance.

To validate feasibility of this novel measurement method, crosstalk and discontinued noise are measured and shown in next two chapters. These items are both critical signal integrity issue which can cause system fail when transmitted speed is over 10Gbps for next technology generation. Novel measurement system will bring better design flexibility while keeping measurement correctness.

3. **Crosstalk Measurement.** In electronics, crosstalk is any phenomenon by which a signal transmitted on one circuit or channel of a transmission system creates an undesired effect in another circuit or channel [8]. Serious signal coupling or crosstalk will always happen at the circuit design for the high-speed measurement. They will make system operate at an unstable situation and even make the system break down. For that, how to get coupling path with low signal coupling or crosstalk becomes a serious issue to design a measuring system. Traditional testing method uses the VNA to detect S-parameters (S_{xy}) or use scope to get unwanted waveform, and then the signals caused by coupling and crosstalk are also included. However, these methods need to place test points on layout and contact with the measuring points. In this process, the measuring probes are taping out on the test points, for that we can be unable to get the high performance of signal coupling. Using this measuring process, more time is needed to find the domination coupling path and that will waste more time to get the accurate measurement. Planar near-field measurements are conducted by scanning a small probe antenna over a planar surface with un-contacting method. In order to get better testing flexibility and performance, near-field instrument is investigated to resolve these problems in this paper.

3.1. **Testing sample design.** The edge couple differential symmetric stripline transmission line is a common technique for routing differential traces. In order to measure the singles with the coupling mechanism, edge-coupled differential pair was designed to implement the novel signal integrity method because differential pair is well investigated in many measuring systems and it is easily to be designed for the special measuring conditions. Figure 4 shows the cross-section structure of the designed differential pair, and Table 2 shows physical parameters, including the width, length, and spacing between two measuring points, and the distance between the two different pairs.

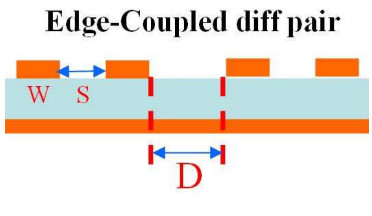


FIGURE 4. Edge-coupled differential pair as testing sample

TABLE 2. Physical parameters of testing samples

Parameter Type	Width (W)	Length	Spacing (S)	Distance (D)
Type A	1.0mm	70mm	0.55mm	0.6/4mm
Type B	1.5mm	70mm	1.65mm	

3.2. **Measurement structure.** Figure 5 shows block diagram for this differential coupling measurement system. VNA port 1 was used as output terminal, and the signals were transferred to balun filter and then being converted into differential signals. After that, the differential signals were directly coupled to the DUT, as the differential coupled pair shown in Figure 4. At the signal receiver terminal, loop antenna probe received the radiation emission into port 2 of VNA and the S-parameters were obtained. Then, post-processing in circuit simulator with transient simulation engine would be carried out to obtain time-domain information.

3.3. **Measurement result.** Figure 6 shows the measurement result of near-end crosstalk with a coupling distance of 0.6mm (Figure 6(a)) and 4mm (Figure 6(b)) at the direction of Z-axis. One differential signal was coupled into differential pair and other terminals were designed to be 50Ohm for avoiding multi-reflection. From the results shown in

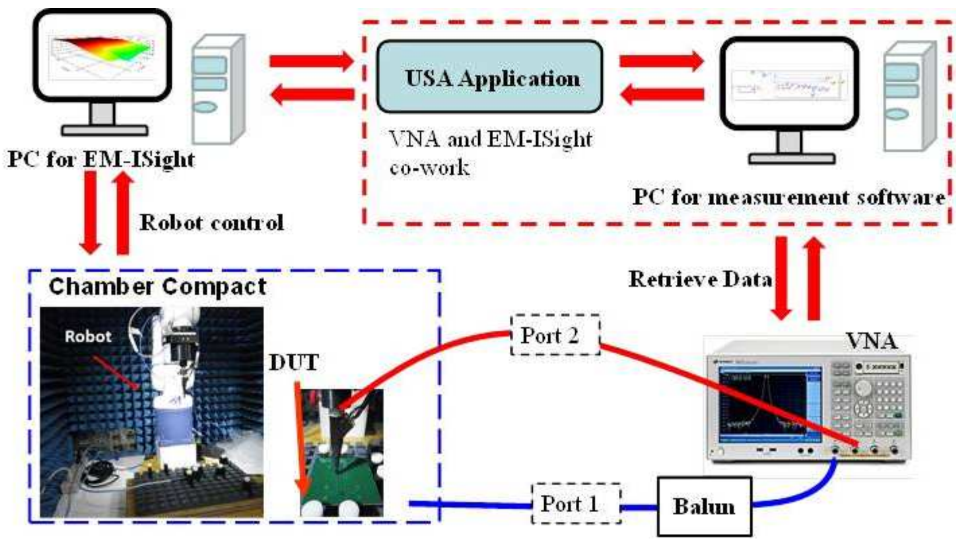
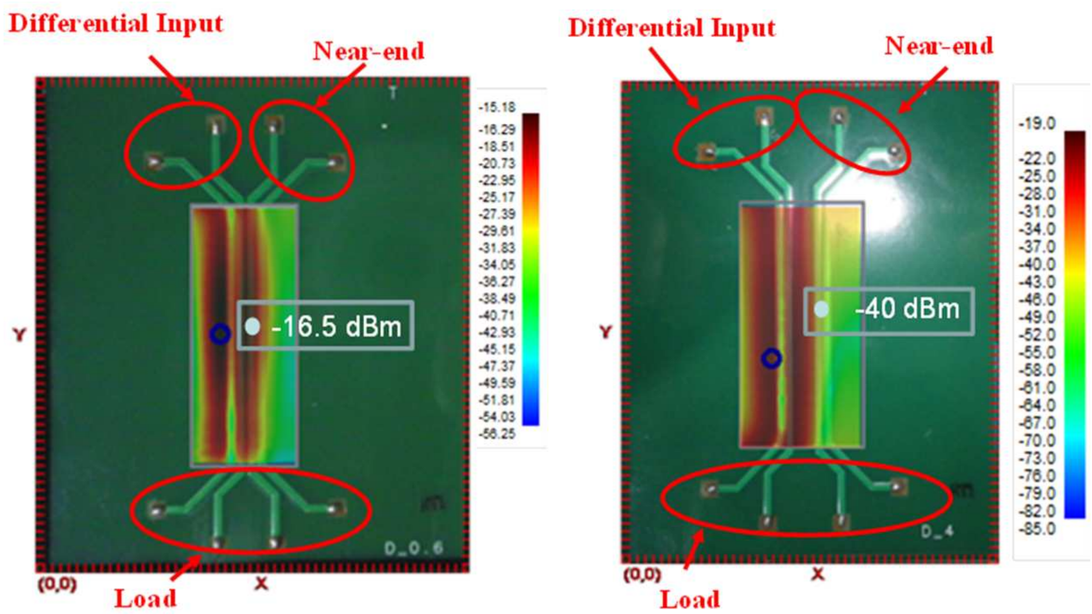


FIGURE 5. Block diagram of differential crosstalk measurement system



(a) (b)

FIGURE 6. Near-end crosstalk measurement results with a distance of (a) 0.6mm (b) 4mm

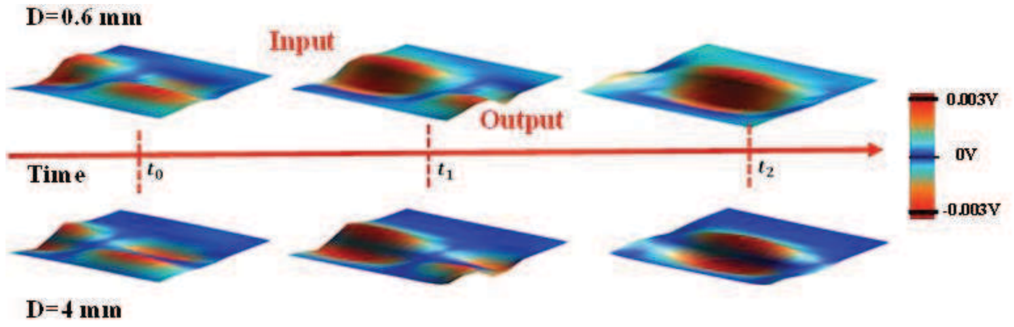


Figure 7. Electromagnetic field pattern for edge-coupled differential pair with different distances

Figure 6, the distance between differential pairs will directly determine the energy of the crosstalk. As the measuring distance was 0.6mm, the return loss of coupling signal was −16.5dBm and the measuring distance was 4mm, the return loss of coupling signal was −40dBm. Those results agree with coupling theorem: the shorter distance between traces is, the worse coupling and less energy will be performed. However, Figure 6 only shows information with one frequency and one time point, and the figure cannot reveal the result changing with the variation of time.

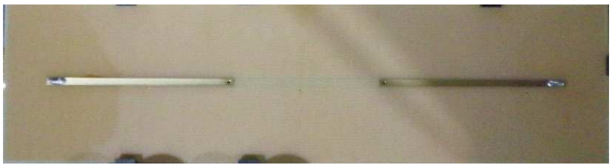
Figure 7 shows the variation of the electromagnetic field pattern with the distances of 0.6mm and 4mm between differential pairs as a function of time variation. At time t_0, the measuring results for edge-coupled differential pair with different distances had identical coupling density. When time was increased from t_0 to t_2, electromagnetic field pattern for different coupling lengths would have different results. Comparing the results in Figure 7, the electromagnetic field pattern for the distance of 0.6mm had larger coupling strength and density between differential pairs.

4. **Discontinued Noise Measurement.** Designing an equipment with high-speed measurement performance the circuit needed having the support of good signal integrity. The first important thing for signal integrity of the designed circuit is that the circuit will have 50Ohms matching impedance or with the assigned characteristic impedance. If impedance from chip output to PCB has been matched, the total loss between the transform will be decreased. The signal Via is a heavily utilized interconnection structure in high-density System-on-Package (SoP) substrates and PCBs [9]. However, it is difficult to design impedance having matching effect with the channel due to manufacture tolerance, buried/PTH signal via and solder ball connection, etc. How to get the signals from discontinued point during the measurement process has become an important issue. Traditionally, the time domain reflectometer can be used to find the points in the fabricated circuits with discontinued signals. However, the time domain reflectometer needs additional measured points and it has been restricted to measure the products having taped-out. Therefore, developing non-contacting or near-field measurement with loop antenna can be used to resolve this problem.

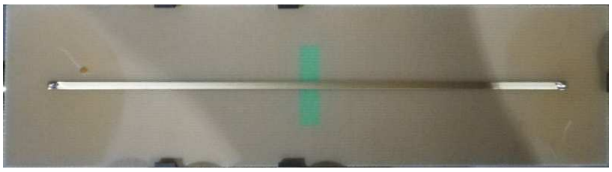
4.1. **Testing sample design.** To test signal reflection or discontinued noise, three test samples with different surface morphology and two-layer substrates were designed, as shown in Figure 8. The first was the microstrip line (Figure 8(a)), the second was microstrip line with holes (Figure 8(b)), and the third was microstrip line with ground slot (Figure 8(c)).

4.2. **Measurement structure.** Figure 9 shows block diagram for this discontinued noise measurement system, which is similar to differential coupling measurement system shown in Figure 5, but balun filter should be removed.

(a)



(b)



(c)

Figure 8. Testing samples for discontinued noise measurement: (a) microstrip line, (b) microstrip line through the hole, and (c) microstrip line with ground slot

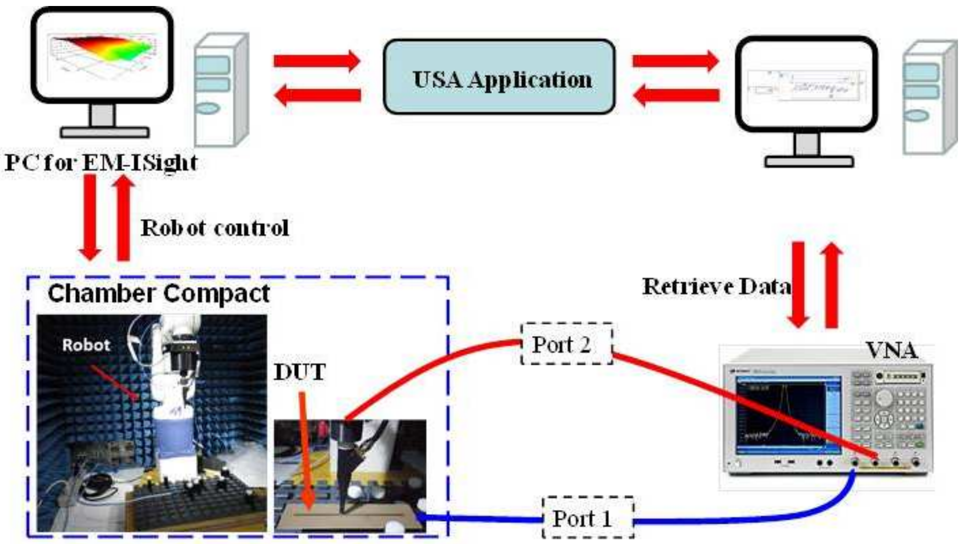


Figure 9. Block diagram of discontinued noise measurement system

4.3. **Measurement result.** The images of the near-field patterns were measured as a variation of time domain and the results are shown in Figure 10, which shows that different testing samples will have different results of signal transmissions. Figure 10(a) is using microstrip line shown in Figure 8(a) to measure the discontinued noises, these results can confirm that this measurement setup and method can get the correct patterns, and the signals transmit forward as a function of time. Figure 10(b) shows the measurement results of signal transmissions on DUT microstrip line with holes, and Via is a discontinued point when signal through and noise will happen in the transmission line. Finally, Figure 10(c) shows measurement results for another discontinued case, signal transmission on microstrip line with ground slot. In this case, the signal transmission has a larger variation

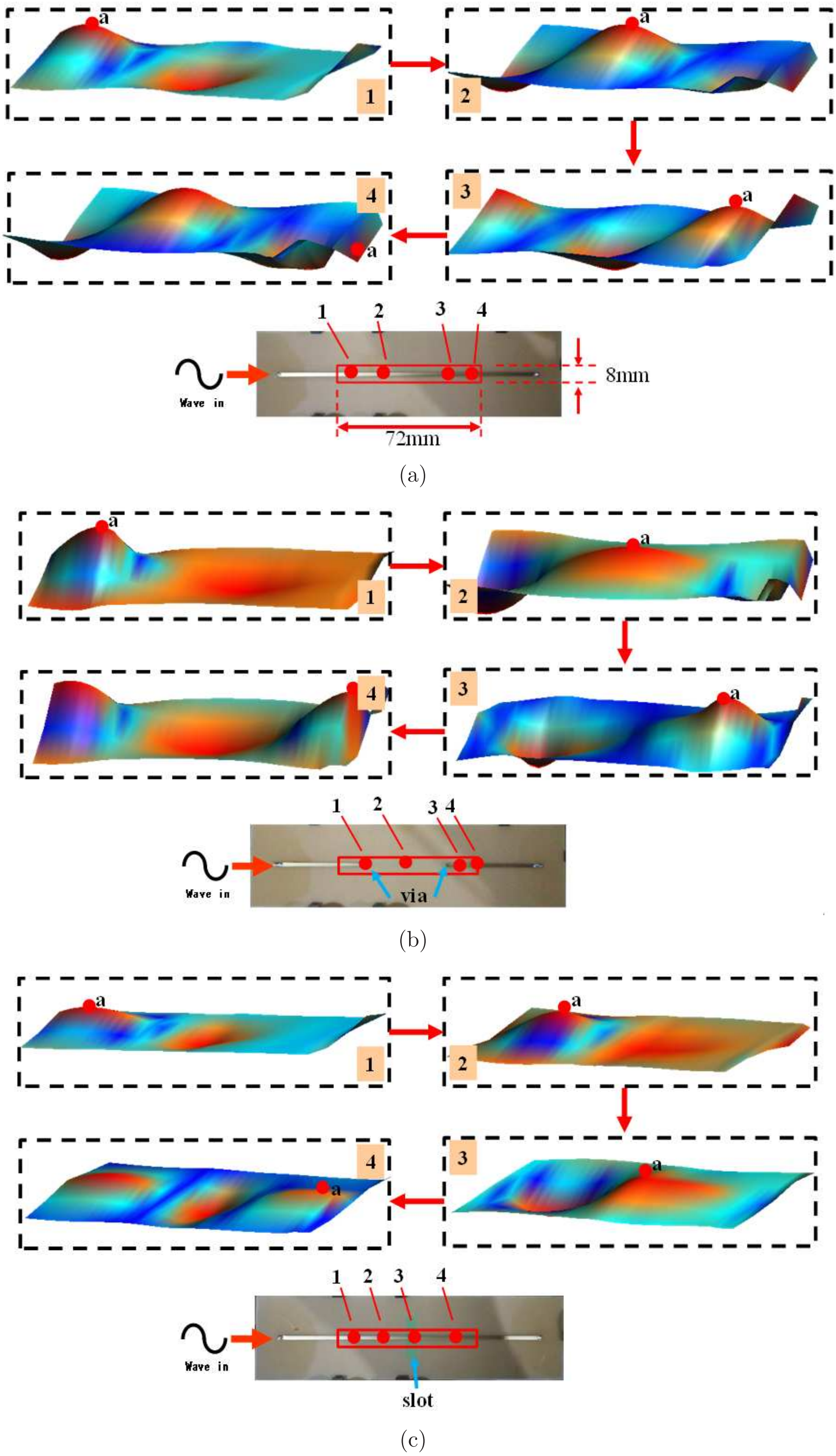


FIGURE 10. Electromagnetic field patterns as a function of time domain: (a) result of Figure 8(a) sample, (b) result of Figure 8(b) sample, and (c) result of Figure 8(c) sample

than that through the Via hole. The result shows that as the signal transmitted through the slot position, the noise would happen and signal decade on latest pattern.

As the electromagnetic field patterns shown in Figure 10, when three different samples and three different kinds of discontinued noise are used to measure the signals with the time domain, we can find that measurement results really provide and reveal the time-variant radiation patterns, and we can get signal happening at DUT and how the noises in the microstrip lines are generated.

5. **Conclusions.** Traditionally, near-field measurement system was taken to measure electromagnetic interference or radiated emission. In this study, we introduced novel signal integrity measurement method by near-field measurement system to measure the coupling signals and discontinued noise in the transmitting or microstrip lines. Using near-field measurement system had the advantages of no need of more measuring points for increasing test flexibility and directly finding the measuring points that would cause the failure in channel. In the future, we had designed and included the measurement technologies of simultaneously switching noises (SSN) and electrostatic discharge (ESD) experiments to enlarge the applications of the near-field measurement system.

Acknowledgement. The authors acknowledge financial supports of Industrial Development Bureau, Ministry of Economic Affairs and Medical Devices and Opto-Electronics Equipment Department, Metal Industries Research and Development Center.

REFERENCES

[1] IEC61967-3, *Integrated Circuits – Measurement of Electromagnetic Immunity, 150kHz to 1GHz – Part 3: Measurement of Radiated Emissions – Near-Field Scanning*, 2005.
[2] C. R. Paul, *Introduction to Electromagnetic Compatibility*, John Wiley & Sons, Inc., New York, 1992.
[3] X. J. Shen, Y. Q. Zou, Y. M. Zhang and X. L. Wu, Planar near field measurement system and computer simulation for UWB radar antenna, *International Conference on Radar*, 2006.
[4] L. Escotte, R. Plana and J. Graffeuil, Evaluation of noise parameter extraction methods, *IEEE Trans. Microwave Theory and Techniques*, vol.41, no.3, pp.382-387, 1993.
[5] R. D. Hayward, Method for obtaining noise parameters using a vector network analyzer with an integrated noise receiver, *Microwave Measurement Symposium (ARFTG)*, 2012.
[6] L. Belostotski and J. W. Haslett, Evaluation of tuner-based noise-parameter extraction methods for very low noise amplifiers, *IEEE Trans. Microwave Theory and Techniques*, vol.58, no.1, pp.236-250, 2010.
[7] E. Bogation, *Signal Integrity – Simplified*, Prentice Hall, 2004.
[8] F. D. Mbairi, W. P. Siebert and H. Hesselbom, On the problem of using guard traces for high frequency differential lines crosstalk reduction, *IEEE Trans. Components and Packaging Technologies*, vol.30, no.1, pp.67-74, 2007.
[9] X. X. Wang and D. L. Su, The Influence of power/ground resonance to via's SSN noise coupling in multilayer package and three mitigating ways, *IEEE 2006 International Conference on Electronic Materials and Packaging*, pp.1-5, 2006.