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Probe-Caused Error Correction Based on Time-Frequency Domain Analysis

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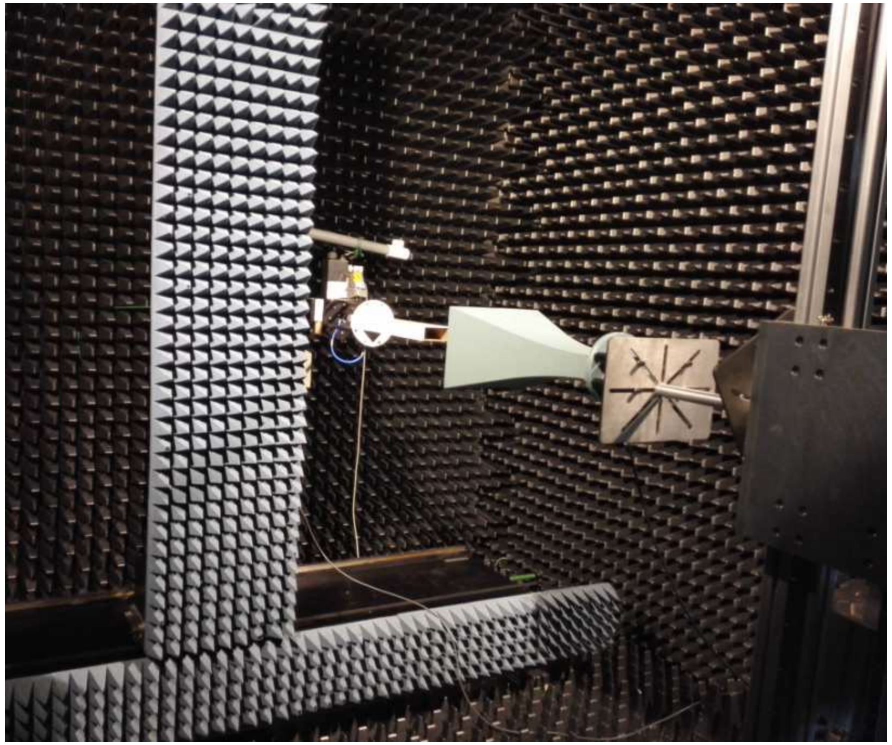
CONTENTS

1 Introduction

Time-domain near-field antenna measurement is a highly efficient testing technology with good confidentiality and all-weather capability[(1)]. Due to the low signal-to-noise ratio acquired in such measurement method, error correction is extremely important[(2)].

Here, we propose a numerical method based on time-frequency domain analysis to modify errors caused by probe modulation.



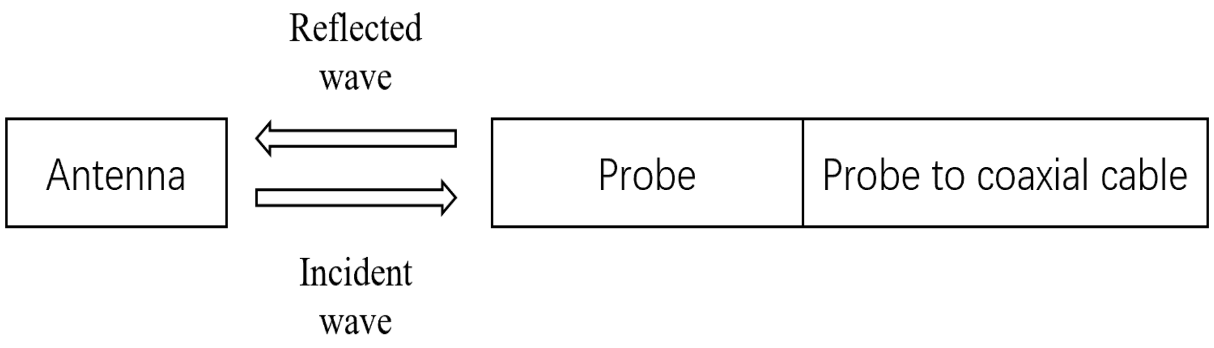
Time-domain near-field antenna measurement system

(1) Zhenghui Xue, Nan Wang, Shiping Lou. Antenna time-domain near-field measurement technology and experiment system [J]. Radio Engineering,2009,39(4):34-36.
(2) M. Cao, Z. Xue, W. Ren, W. Li, R. Zhu, H. Cai, The research of errors in time domain near field measurement[C], 2016 IEEE Conference on Antenna Measurements & Applications (CAMA), pp. 1-3,2016.

Analysis of probe modulation

Probe-caused error in antenna measurement system is unavoidable. Some researchers use time-domain deconvolution to deduct the time-domain receiving characteristic of the probe from the receiving signal[1]. But it's hard to realize.

Luckily, a waveguide (probe) is a passive device, amplitude attenuation and phase change of the signal at the same frequency point are consistent. Which makes the adoption of Fourier transform possible, providing a solution for error correction based on time-frequency domain analysis.



Signal receiving procedure in the near-field antenna measurement system

(1) T.B. Hansen, Formulation of spherical near-field scanning for electromagnetic fields in the time domain [J], IEEE Transactions on Antennas and Propagation, vol. 45, pp. 620-630, 1997..

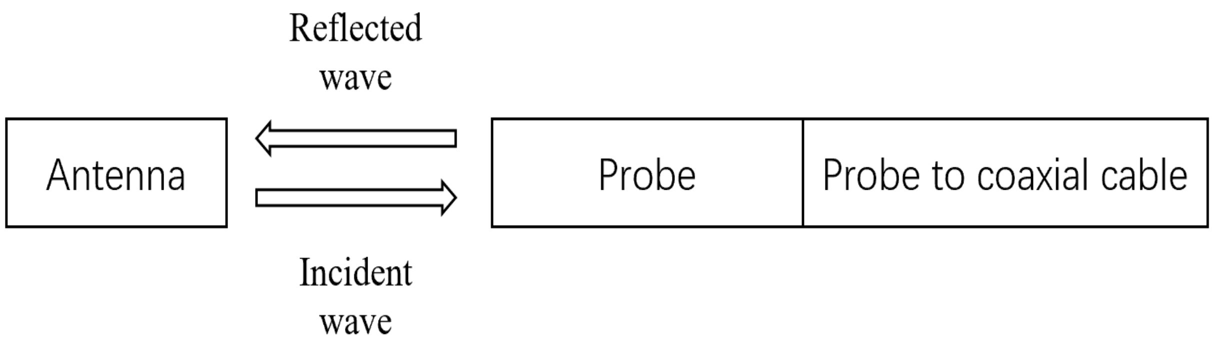
2 Analysis of probe modulation

Modulation function of the probe can be expressed as[1]

$$H = I_1 \cdot I_2 \cdot I_3$$

When only main mode transmission is considered and mismatch between the waveguide and coaxial line is ignored, H can be calculated and represent as[1]:

$$H = jw\left[1 + ref + (1 - ref)\frac{\beta c}{\omega}\right]\frac{be^{-(\alpha_c+\alpha_d+j\beta)\cdot d}}{\pi^2 c}$$



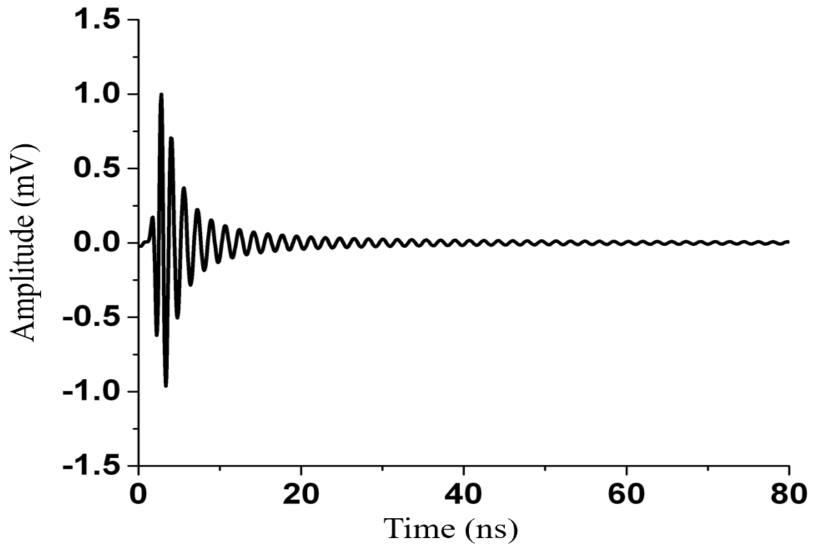
Signal receiving procedure in the near-field antenna measurement system

(1) Hongchen Shang, Zhenghui Xue, Runqing Yan. Fundamentals of microwave technology[M]. 2005

2 Analysis of probe modulation

$$H = jw[1 + ref + (1 - ref)\frac{\beta c}{\omega}]\frac{be^{-(\alpha_c+\alpha_d+j\beta)\cdot d}}{\pi^2 c}$$

H is a function of frequency. It can be expressed in the time domain by Fourier transform. Time-domain modulation function of the waveguide probe is as follows:



Time-domain modulation function of the probe

Probe modulation correction

According to the formula below:

$$H = jw[1 + ref + (1 - ref)\frac{\beta c}{\omega}]\frac{be^{-(\alpha_c+\alpha_d+j\beta)\cdot d}}{\pi^2 c}$$

the modulation function of the probe is determined once the structure of the probe is determined, which can be obtained by numerical calculation. Convolution in time domain can be considered as point multiplication in frequency domain.

According to the probe input signal a and probe-sampled signal c, the corresponding frequency domain signals A and C can be obtained with Fourier transform. Then the frequency domain expression of the probe modulation function B can be obtained.

Probe modulation correction

With the inverse Fourier transform, time-domain expression of the probe modulation function can be acquired. The whole procedure can be expressed as:

$$a = ifft(A) = ifft(C/B)$$

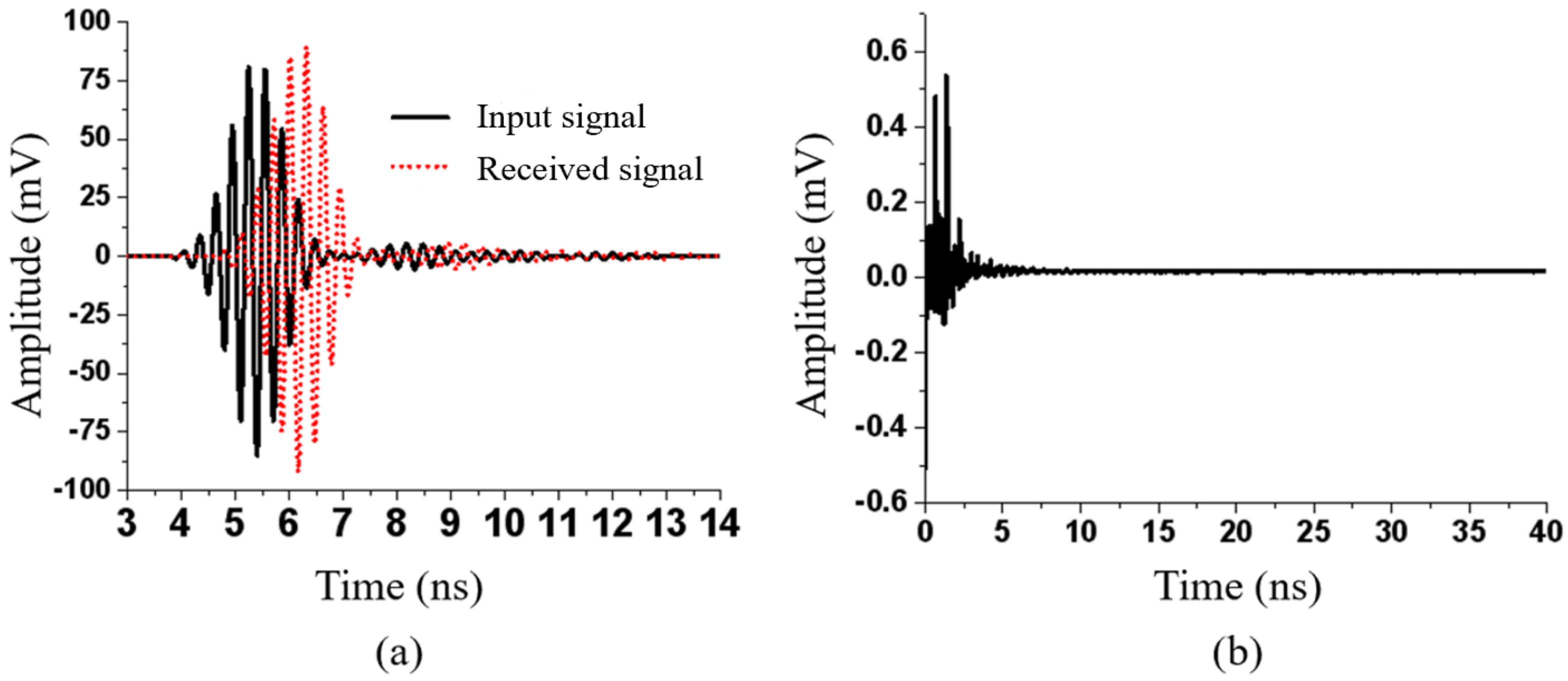
Now traditional deconvolution problem is replaced by one time Fourier transform and one-time division of complex numbers. The number of sampling points has little influence on calculation speed, which makes it a fast way to process. The uniqueness of Fourier transform and inverse Fourier transform can guarantee the solvability of the problem.

Probe modulation correction (Simulation)

- Simulations were done to verify this method.
- An S-band standard horn antenna is excited with 2.6 – 4 GHz Gaussian signal, the distance between sampling probe and standard horn antenna is 300 mm, the sectional dimension of the sampling waveguide probe is 72.14 mm × 34 mm and the length of the probe is 80 mm.

Probe modulation correction (Simulation)

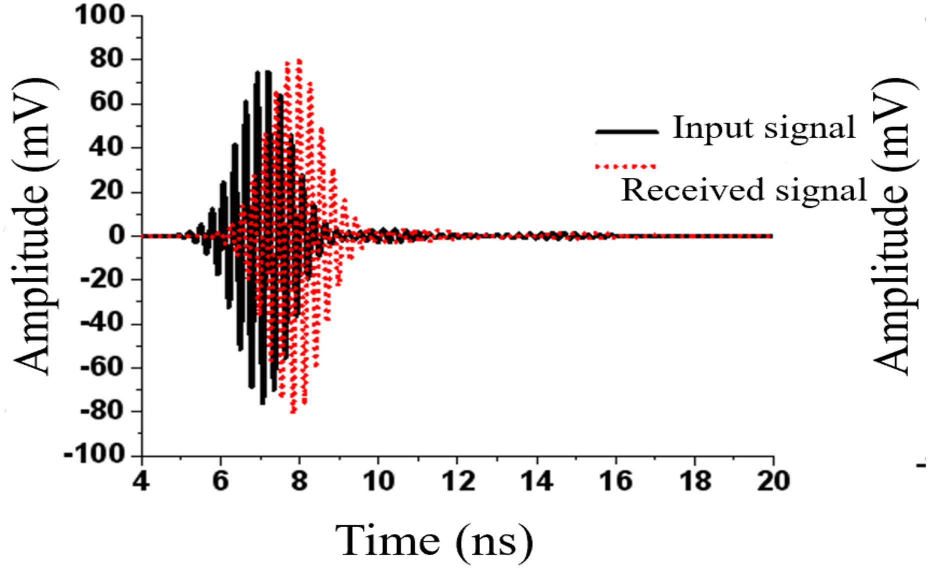
The following figure shows the input signal, the received signal, and the calculated time-domain waveguide modulation curve. This time-domain waveguide modulation function can be used for all-band signal correction received by this waveguide probe.



(a)input signal and received signal (b)the calculated time-domain waveguide modulation curve.

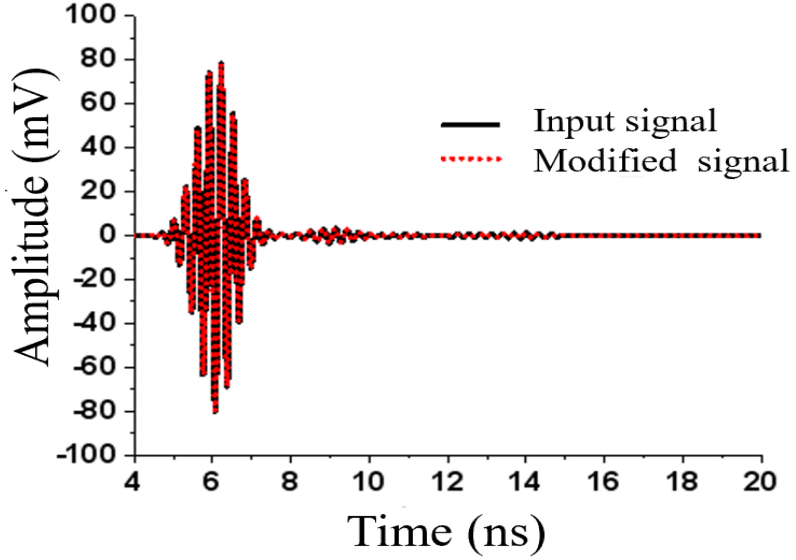
Probe modulation correction (Simulation)

Input signal and received signal



(a)

Input signal and modified signal

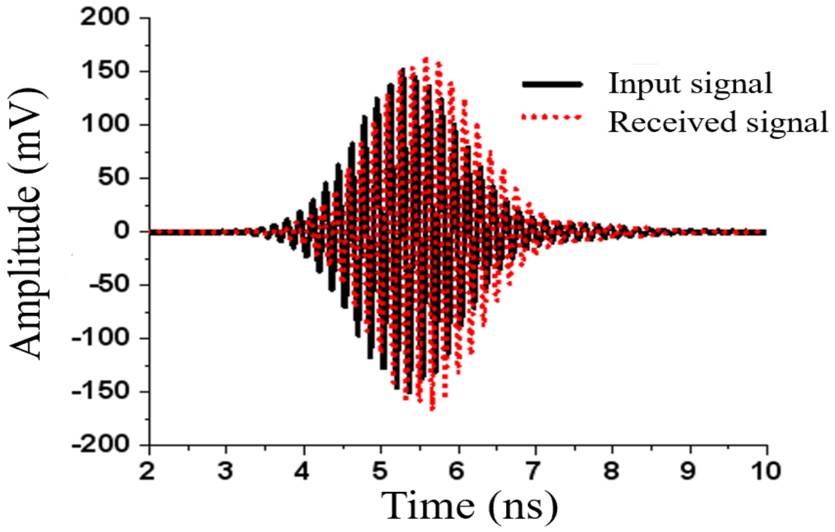


(b)

S-band simulation results

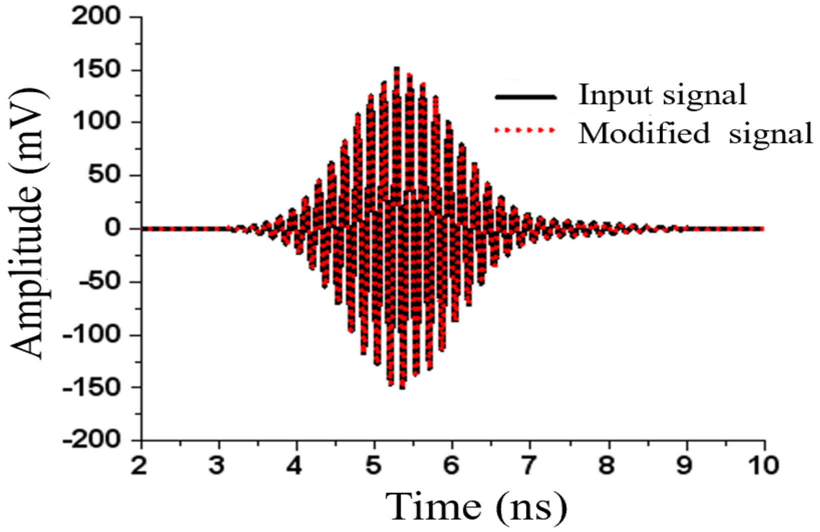
Probe modulation correction (Simulation)

Input signal and received signal



(a)

Input signal and modified signal



(b)

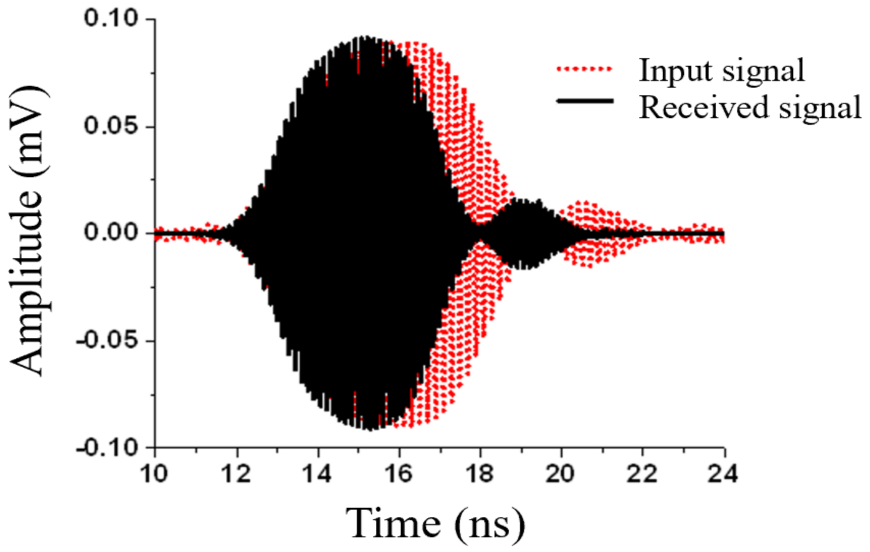
C-band simulation results

Probe modulation correction (Experiment)

- Similar to the simulation results, experiment results also proved the effectiveness of this method.
- NSI standard horn and standard open waveguide were used. An experiment was carried out in C-band, waveguide used here is NSI-RF-WR137 with a working band of 5.8-8.2GHz. The waveguide probe is placed in the center of the sampling plane, facing the horn antenna.

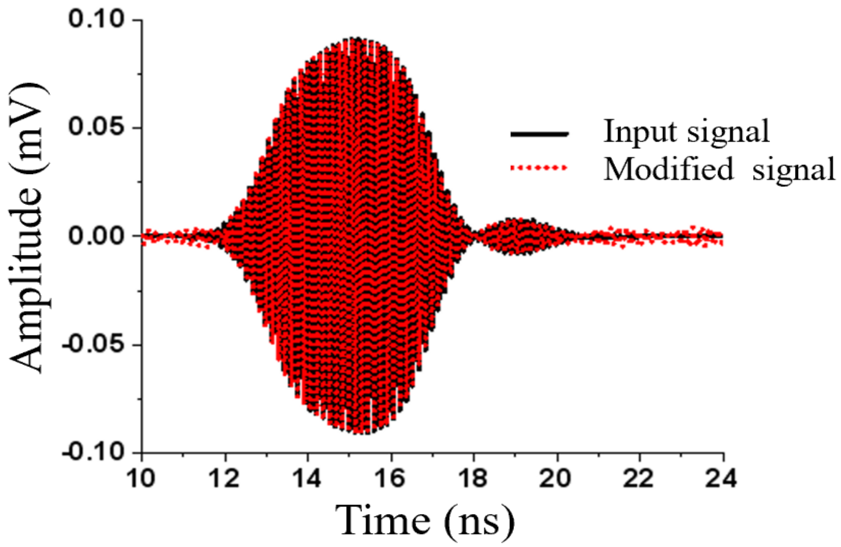
Probe modulation correction (Experiment)

Input signal and received signal



(a)

Input signal and modified signal



(b)

C-band experiment results

Conclusion

- An error correction method based on time-frequency domain analysis is proposed. The feasibility of the method is proved by simulations and experiments.
- Time-domain near-field antenna measurement can realize broadband and ultra-wideband measurement with one-time test, which can improve measurement efficiency and reduce cost. Further research needs to be done on error correction to realize engineering application.

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The End
Thank you!

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