Improvement of setup calibration for radar cross section measurements

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ABSTRACT

This paper aims to present a calibration optimization method for radar cross section measurement setup using time domain measurements. The proposed method requires a measurement of S_{21} parameter of a metallic plate with a known RCS at 13 different distances. A post processing technique reveals the correlations between the distances of measurements and time domain representations of S_{21} extracted parameter. Time-domain representation of S_{21} also depends on the wave propagation time on the antenna (Vivaldi and log-periodic) feeding line which inserts a delay. Time domain perspective clearly provides propagation delay data on antennas which are almost undetectable in frequency field. The principles of this method are provided together with experimental and simulation validations. At a distance of 22cm between antennas, mutual coupling influence affects every measurement set and is being reduced in post processing. This method also provides the impulse response of the whole measurement setup.

Keywords: calibration, time domain, delay, mutual coupling

1. INTRODUCTION

Radar cross section (RCS) measurements are generally performed in far-field conditions. External factors have an important influence upon these measurements. Time-domain near-field perspective can provide an interesting alternative to conventional RCS measurement methods. Having the advantage of obtaining an ultra-wide band RCS analysis from one single measurement, the near-field error reduction algorithms become more important [1], [2]. The usual calibration technique is SLOT method. This technique is not accurate in all frequency range and for all MUT types [3]. Time domain analysis reveals necessity of calibration corrections.

This paper presents a RCS calibration method with a radar-type setup. The proposed post processing technique finally reveals the correlation between S_{21} data and the distances. For measurements in the 850MHz–3GHz band, log-periodic and Vivaldi antennas become a smaller size alternative to horn antennas. The distance between antennas is comparable to the length of the log-periodic and Vivaldi antennas and the mutual coupling effect is reduced by post-processing.

2. DESCRIPTION OF THE METHOD AND EXPERIMENTAL ANALYSIS

The measurement setup consists of two identical log-periodic antennas excited on the frequency range 800MHz-3GHz, a metallic plate with a known RCS, and a vector network analyzer (VNA). This log-periodic printed circuit board antenna was designed for frequencies from 850MHz-6500MHz. At a distance of 22cm between antennas, the effect of the mutual coupling is reduced by post processing. The measurement is also done with an identical set of Vivaldi antenna in the

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same band (800MHz-3GHz). The radar-type measuring system with log-periodic antennas is given in figure 1 and radar-type measuring system with Vivaldi antennas is given in figure 2.

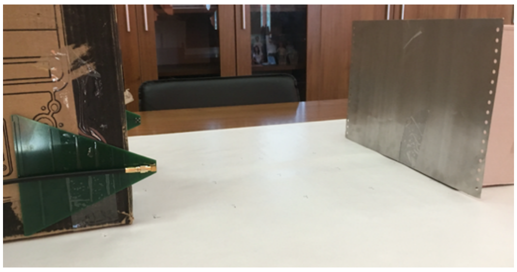

Figure 1. Bistatic radar-type with log-periodic antennas

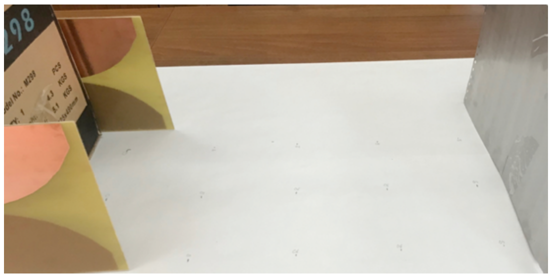

Figure 2. Bistatic radar-type with Vivaldi antennas

The time domain S_{21} calculation is already done in [4] and [5] obtaining good results for interpretation with the inverse fast Fourier transform technic:

$$s_{21}(t) = F^{-1}\{S_{21}(\omega)\} \tag{2}$$

The ultra-wide band comportment of log-periodic arrays in time-domain is oscillatory since the log-periodic arrays resonate around specific frequencies. Based on the distance calculation formula, for the black trace in figure 3 one obtains 114cm at a time of 7.64ns. This result does not fit with the distance of 90cm at which measurement was performed. Theoretically

$$t = \frac{2d}{c_0} \tag{1}$$

for 90cm t=6ns. The difference Δt = 0.82ns for each antenna (corresponding to a feeding line length of 24cm) represents a systematic delay which affects entire measurement setup.

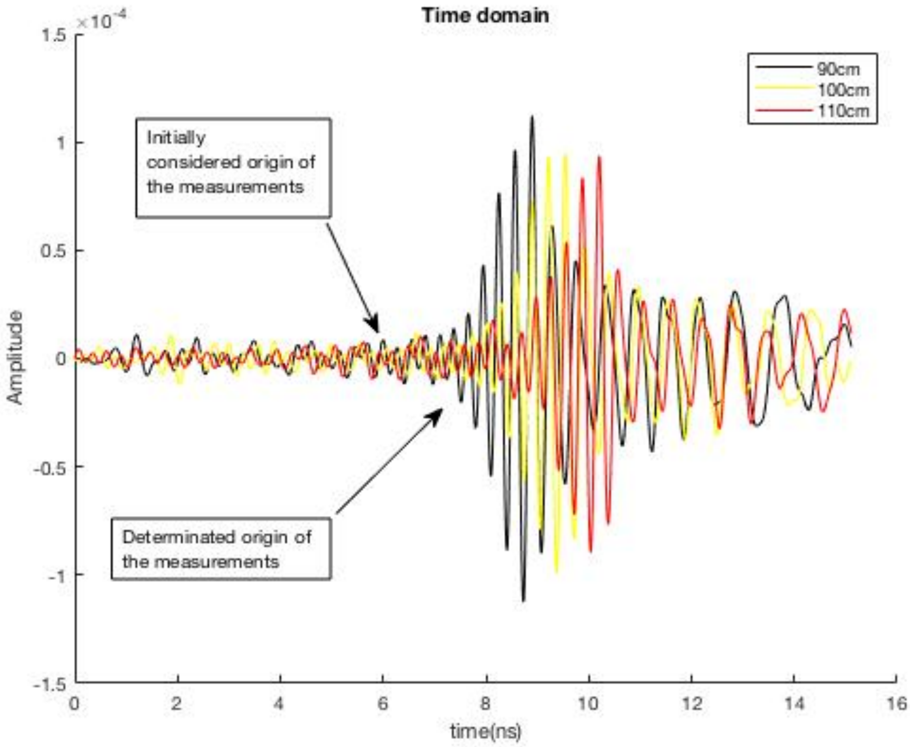

Figure 3. Time-response for the distance between antennas and target of 90cm, 100cm and 110cm

The schematic representation of the real position of the log-periodic antennas is presented in figure 4.

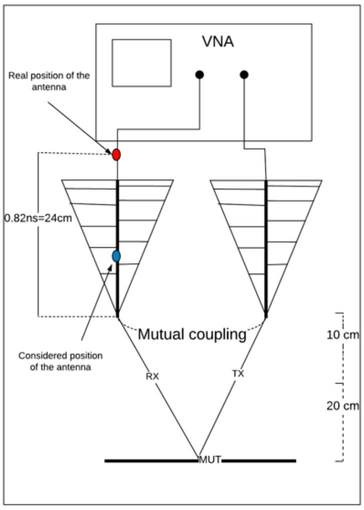

Figure 4. Schematic representation of the real position of the log-periodic antennas

The two identical Vivaldi antennas excited over 800MHz – 3GHz frequency range, a metallic plate with a known RCS and a VNA compose the second measurement setup. The distance between Vivaldi antennas was 22cm and the distances between antennas and the metallic plate was consecutively set at 80cm, 90cm, 100cm and 110cm. Figure 5 is a time domain representation of the S_{21} parameter measured at 4 distances. This distances were based on the far-field time-domain conditions [6].

Based on the distance calculation formula, for the magenta trace in figure 5 one obtains 1.005 m at a time of 6.7 ns. This result does not fit with the distance of 80cm at which measurement was performed. Theoretically $t=2d/c_0$ for 80cm equals 5.33ns. The difference Δt=0.68ns for each antenna (corresponding to a feeding line length of 10 cm) represents a systematic delay which affects entire measurement setup. That is, the antenna feeding line introduces a 0.7ns delay which affect total propagation time.

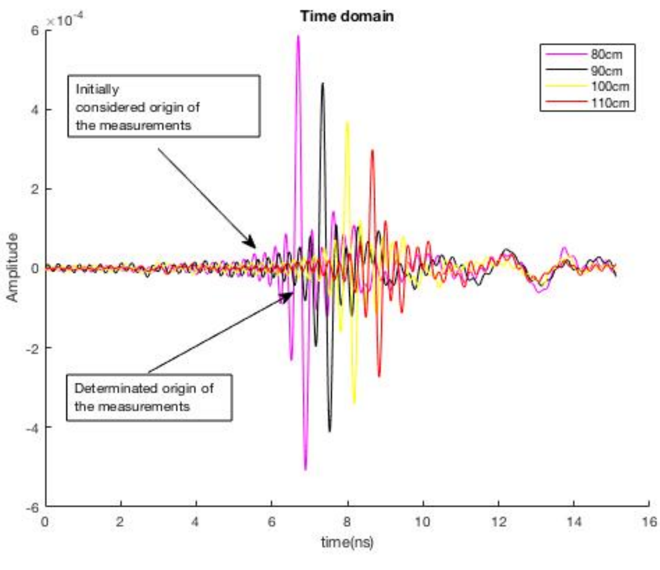

Figure 5. Time domain representation of S_{21} parameter at different distances

The schematic representation of the real position of the log-periodic antennas is presented in figure 6.

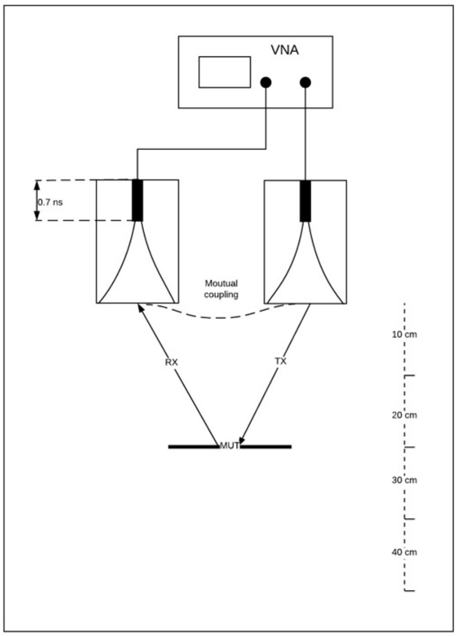

Figure 6. Schematic representation of the delay on the bistatic radar-type with Vivaldi antennas

3. CONCLUSIONS

This time-domain evaluation of the measurement setup for radar cross section is necessary for an accurate calibration of the measurement setup. The technic we propose in this article can also be applied to antenna gain measurements [7] and [8]. We proposed a time-domain technique to evaluate the position of the antennas for RCS measurements in the 800MHz – 3GHz band using a set of log-periodic antennas and Vivaldi antennas. It should be emphasized that the position of the log-periodic antennas may be situated with 24cm outside of the initially considered position and with 10cm outside of the initially considered position for Vivaldi antennas. The purpose of such an evaluation is solely to accurately assess the distances between antennas and the target provided, the size of the antennas and the target being comparable to the range. Basically the wave velocity on the array feed line is less than the speed of light but the speed of light is used instead in our evaluation since RCS measurements need and equivalent distance between the antennas and target. Also, this analysis is necessary in low frequency measurements for a correct positioning of the antenna.

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