The effect of the antenna group delay on RCS measurements in the L-band

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When measuring the radar cross section (RCS) at a distance in the same order as the antennas and the target sizes the range should be accurately assessed. In the L-band the use of highly directive antennas such as horn antennas is restricted by the size they would have. We propose therefore to use a pair of log-periodic arrays instead although they are less directive and supposed to exhibit a stronger mutual coupling. A differential technique based on subtracting the impulse response with and without target is also proposed. The method was successfully validated on a rectangular target.

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***Abstract*—When measuring the radar cross section (RCS) at a distance in the same order as the antennas and the target sizes the range should be accurately assessed. In the L-band the use of highly directive antennas such as horn antennas is restricted by the size they would have. We propose therefore to use a pair of log-periodic arrays instead although they are less directive and supposed to exhibit a stronger mutual coupling. A differential technique based on subtracting the impulse response with and without target is also proposed. The method was successfully validated on a rectangular target.**

***Index Terms*—radar cross section, delay, time domain, S-parameters**

I. Introduction

Radar cross section (RCS) measurements are generally performed in far-field conditions. This expensive configuration is sensitive at the influence of external factors. Time-domain near-field perspective 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]. By gating the response of the target good time-domain RCS results can be obtained. The evaluation of the time-domain representation of S_{21} is a mandatory intermediate step to acquire RCS results [3]. The expression of the group delay (GD) for two isotropic radiators in the free space is [4]:

$$GD = \frac{d}{c} \tag{1}$$

If the isotropic radiators are replaced by the real antennas, the GD in (1) should be increased,

$$GD = \frac{d}{c} + GD_{antenna1} + GD_{antenna2} \tag{2}$$

This paper presents a RCS analyzing method with a radar-type setup. The proposed post processing technique finally reveals the correlation between S_{21} data and the group delay. For measurements in the L-band, log-periodic antennas become a smaller size alternative to horn antennas. The distance between antennas is comparable to the length of the log-periodic antennas and the mutual coupling effect is reduced by post-processing. The technique that we propose in this article can also be applied with the distance averaging method [5], [6].

II. 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 analyser (VNA). This log-periodic printed circuit board antenna was designed for frequencies from 850 - 6500 MHz. At a distance of 22cm between antennas, the effect of the mutual coupling is reduced by post processing. The radar-type measuring system is given in fig 1.

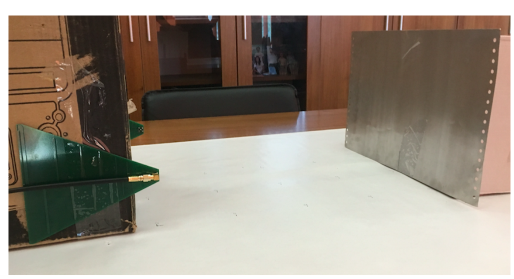

Fig. 1. Radar-type measurement setup

The time-domain representation S_{21} was computed by an inverse Fourier transformation [7], [8]:

$$s_{21}(t) = F^{-1}(S_{21}(\omega)) \tag{3}$$

The distances between the antennas and the metallic plate was consecutively set at 90, 100 and 110cm.

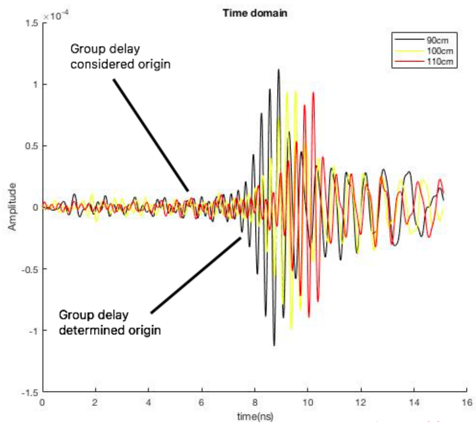

Fig. 2. Time-response for the distance between antennas and target of 90cm, 100cm and 110cm

The time-domain response of the entire system is oscillatory since the log-periodic arrays resonate around specific frequencies. Based on the distance calculation formula, for the black trace in fig. 2 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

$$t = \frac{2d}{c_0} \tag{4}$$

for 90cm equals 6ns. The difference $\Delta t = 0.82ns$ for each antenna (corresponding to a feeding line length of 24cm) represents a systematic delay which affects entire measurement setup. Practically, the $GD_{antenna1} = GD_{antenna2} = 0.82ns$ and the total GD is

$$GD = \frac{d}{c} + 1.64 \tag{5}$$

The GD measurement setup is presented in fig.3.

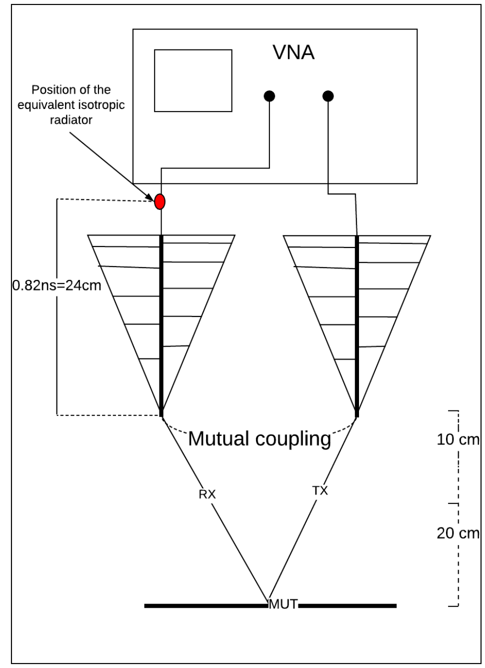

Fig. 3. Representation of the group delay (GD) measurement setup

III. Conclusion

We proposed a time-domain technique to evaluate the position of a group-delay center for RCS measurements in the L-band using a set of log-periodic antennas. It should be emphasized that the position of the group delay center may be situated outside of the physical structure of the antenna as 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 are comparable to the range. Basically the group 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 with respect to group delay origin. Also, the origin of group delay is necessary in low frequency measurements for a correct positioning of the antenna.

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