Experimental Proof of the Characteristics of Short-range FM Radar Converted Signal Spectrum for a Smooth Surface

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Abstract – This paper presents a natural experiment of the spectral processing of 4.3GHz Frequency Modulated Continuous Wave Radar (FMCWR) converted signal. The FMCWR antennas are fixed above a smooth reflective surface. The converted signal spectrum is theoretically calculated and compared with the experimental data.

Keywords – Frequency Modulated Continuous Wave Radar (FMCWR), converted signal spectral processing, smooth reflective surface, mirror reflection

I. INTRODUCTION

The FMCWR (Frequency Modulated Continuous Wave Radar) is widely used for precise distance measurements. The simplest FMCWR does not require a linear modulation waveform. Sinusoidal or almost sinusoidal frequency modulation is easier to obtain with practical equipment [1], [2]. This principle was applied for an aircraft altimeter in the 1930s [3]. Any reasonable-shape modulation waveform can be used to measure the range, provided the average beat frequency is measured. The distance is then extracted from the beat frequency by the integral method [4]. The integral method of converted signal processing does not allow multi-target resolution [1]. The spectral methods of converted signal processing allow to extract additional information from the converted signal as well as to provide multi-target resolution. In this paper, the theoretically calculated spectrum of converted signal is compared with the signal spectrum obtained at the output of the 4.3 GHz FMCWR experimental setup. The reflection of the mirror surface is considered.

II. THEORETICAL BACKGROUND

The propagation speed of electromagnetic waves depends on the composition of environmental air. The radial movement of FMCWR antennas or the reflective surface results in the Doppler shift of the reflected frequency. The given experiment is performed in a stable air environment; therefore the delay of the reflected signal must present a linear function of the distance. The radar antennas and reflective surface are securely fastened so that no Doppler shift is possible.

All the following mathematical expressions are made on the assumption that modulation period $T_M$ is many times greater than time delay $\tau$ of the reflected signal [5]. $T_M >> \tau$ criterion is true if the modulation period is at least ten times greater than the time delay of the reflected signal [4].

The instantaneous frequency of the converted signal can be expressed by formula [4]:

$$\Omega_{\text{conv}}(t, \tau) = \left. \frac{d\gamma(t')}{dt} \right|_{t' = t - \tau/2};$$

where

$\Delta\omega$ radiated frequency deviation;
$\tau$ time delay of the reflected signal;