ANALYSIS OF PHASE RELATIONSHIPS BETWEEN RADAR SIGNALS IN ACOUSTOOPTIC PROCESSING SYSTEMS

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Abstract

The performance and the salient operation features of an interference correlator with a modified optical twin-wave Rayleigh interferometer system in the mode of measurements of phase shifts between radar signals are considered. Such measurements for signals received from two antennas provide information on the angular position of an object or its displacement. A system wherein radio signals are fed for processing into a correlator with the aid of a double acoustooptical cell with a paratellurite acoustic line is experimentally realized and investigated. We consider the modes of system operation when a signal is generated in the regions of the extrema of the correlation functions and in the regions of their strongest variation (extrema of the derivatives). The accuracy of measurements obtained experimentally for the phase shifts between radio signals reaches 0.003 rad to give an accuracy of determining the signal time delays of the order of 0.005 ns in the frequency region of 100 MHz.

Introduction

Radar methods for determining the angular position of an object or its displacement involve measuring the phase shifts or time delays of radio signals generated by two antennas. The setup for radar measurements of the angular position of an object using two antennas is depicted in Fig. 1. The radar signals $U_1(t)$ and $U_2(t)$ from the object Obj arrive at antennas $A_{n1}$ and $A_{n2}$. The phase shift $\Phi$ between the signals, which is of practical interest, is determined from geometric relations. For object-to-antenna distances $L_1$ and $L_2$ and interantenna separation $l$, the difference in the distances

$$dL = L_2 - L_1 = l \sin \alpha,$$

where $\alpha$ is the angular coordinate of the object. For signal time delay $\delta t = dL/c$, the magnitude of the phase delay $\Phi$, in terms of the carrier frequency $\Omega$ and the wavelength of the radar signal $\Lambda$, equals

$$\Phi = \Omega \delta t = \frac{\Omega}{c} dL = \frac{2\pi dL}{\Lambda}.$$

The value of $\Phi$ or $\delta t$ is determined in the measuring unit $M$, allowing one to calculate $dL$ and eventually find the quantity of immediate interest

$$\alpha = \frac{dL}{l} = \frac{c\delta t}{l} = \frac{\Phi c}{\Omega \delta t}.$$

The use of an interference correlator with a twin-wave Mach–Zehnder interferometer system [1-4] as a measuring unit for solving such problems is considered in [5-9]. Measurements were taken for model signals with a phase structure. The principle of measurement consisted in determining the variation of the correlation

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function [10] derived under changes in the phase delay as the radiation passed through the acoustooptical cells placed in two arms of the interferometer.

In this work, we discuss the system performance and the characteristics of the output signals of a measuring unit in the form of a correlator with a modified optical twin-wave Rayleigh interferometer system and of radio signals at frequencies of the order of 100 MHz. The system was chosen for the following reasons. Identical acoustooptical cells should be used to ensure reliable measurements of phase shifts. This condition is readily fulfilled by a double cell built in one crystal. The use of a double cell involves employing an interferometer system with closely located channels. Moreover, the cells in the interferometer arms should be positioned identically. Though of poor efficiency for luminous flux, a Rayleigh interferometer system complies nicely with these requirements. Such positive properties of a Rayleigh interferometer as simplicity and stability of adjustment and reasonable ease of monolithic fabrication are also noteworthy. In addition, we point out that a correlator system based on a twin-wave interferometer ensures good equilization of the optical path lengths, which reduces the requirements on coherence of the radiation source used [2–4]. Since interferometers operate with light fields, processing is basically executed for amplitude-phase signals.

The operation of a correlator employing acoustooptical cells in the Bragg diffraction mode for measuring radio signal delays is studied experimentally in this work. The signals formed in the first diffraction order are analyzed. We examine the effect of a phase delay additionally introduced between the signals, allowing one to alter the system performance. Fairly simple approaches based on the assumption that the efficiency of radiation conversion by diffraction was low were adopted to describe the correlator operation. These approaches allow one to gain solid information on phase relations, although only approximate distributions of light signal intensities in different orders are thereby obtained. It is the phase relations in the interference pattern that are the governing ones when measuring small phase shifts or time delays of radio signals through the use of an interference correlator.

1. Radar Signals in an Acoustooptical Cell

The radar signals with carrier frequency \( \Omega \)

\[ U_1(t) = a_1U(t) = a_1U_0(t)\exp(-i\Omega t) , \]