IIIGIII,Y LINEAR, WIDERANGE, SWEPT 1UWQUINC% GENERATION AT MICROWAVE AND OPTICAL FREQUENCIES

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The resolution of synthetic aperture radar is limited by the frequency range and linearity of the transmitted swept frequency signal. Substantial improvement of the range and linearity of todays all electronic swept frequency generators has proven difficult. We present a new approach using an optical delay line to linearize the sweep rate of swept microwave or optical signals.

Highly 1 hear, Wide-Rat~ge, Swept Frequency Generation at Microwave and Optical Frequencies *

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Abstract

The resolution of synthetic aperture radar is limited by the frequency range and linearity of the transmitteds wept frequency signal. Substantial improvement of the range and linearity of today's all electronic swept frequency generators has proven difficult. We present a new approach using an optical delay line to linearize the sweep rate ofs wept microwave or optical signals.

Int reduction

Several researchers have described a frequency-domain technique which uses a linearl y swept frequency signal to obtain range and amplitude information from multiple reflections in fiber optic systems[1,2,3]. The radar community refers to this technique as Frequency-Modulation Continuous-Wave or FMCW[4]. In these systems a linearly swept frequency signal is transmitted to one or more reflections. When the system receives the reflected signal it is heterodyned against the transmitted signal and produces a low frequency composite signal. This composite signal is analyzed to obtain the range and relative magnitude information for each reflection.

in this paper we describe a technique which uses a fiber optic delay line and FMCW in reverse to generate highly linear swept frequency signals. in turn, the linearly swept frequency signal that is generated can be used to improve FMCW systems such as optical and microwave radar systems, frequency domain reflectometers, fiber optic distributed sensor querying systems, and metrology systems for surveying and precise distance measurements.

Range resolution for FMCW systems depends on the linearity of the frequency sweep. If the frequency sweep is not linear the range information is smeared. This limits the accuracy of the range information and the minimum resolvable d istance between reflections.

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Range resolution also depends on the frequency range of the swept frequency. It is difficult to achieve highly linear frequency sweeps over a large frequency range using traditional techniques . However, The technique described here can achieve highly linear frequency sweeps over a very wide frequency range. For example it can linearize the sweep of an optical frequency over a terahertz frequency ranges.

Description

Referring to Fig. 1, a swept frequency signal is applied to the input of a fiber optic delay line. in the case of an RF or microwave swept frequency signal generator the signal is transmitted through the optical delay line as amplitude modulation on an optical carrier.

The phase of the input signal can be described by,

$$\varphi_{in} = \int_0^t (\omega_0 + \alpha t)\, dt = \omega_0 + \frac{1}{2} \alpha t^2 \tag{1}$$

where, ω_0 = the starting frequency,

t = the time, and

$\alpha = d\omega/dt$ = the frequency sweep rate.

The phase at the far end of the delay line is,

$$\begin{aligned} \varphi_{out} &= \int_0^{t+\tau} (\omega_0 + \alpha t)\, dt = \omega_0 (t+\tau) + \frac{1}{2} \alpha (t+\tau)^2 \\ &= \omega_0 t + \frac{1}{2} \alpha t^2 + \omega_0 t + \frac{1}{2} \alpha \tau^2 + (\alpha\tau)\, t \end{aligned} \tag{2}$$

where, τ = the delay of the delay line.

The difference in phase between the input and output of the delay line can be obtained with a phase detector and is, from (1) and (2),

$$\Delta\varphi(t) = \varphi_{out} - \varphi_{in} = \omega_0 \tau + \frac{1}{2} \alpha t^2 + (\alpha\tau)\, t. \tag{3}$$

Filtering out the DC terms and assuming the input frequency is changing linearly with time the output can be expressed as a frequency, U', by dividing both sides of (3) by t,

$$\omega' = \frac{d(\Delta\varphi)}{dt} = \alpha\tau . \tag{4}$$

From (4) if the delay, τ, is constant and the output frequency, ω', is constant then the slope, α, must be constant. In this system the output frequency, ω', is forced to be constant by phase locking it to a fixed frequency reference. This is done as shown in Fig. 2.

A ramp generator sweeps the frequency of a voltage cent rolled oscillator which in turn amplitude modulates a laser's optical output signal. The polarization of the optical signal from the laser is changed from its inherent linear polarization to circular polarization by passing it through a quarter-wave plate.

After the quarter-wave plate the light is separated into two signals by a polarizing beam splitter. Each of these two signals takes a different path. One of these optical signals is applied directly to a photodetector and the resulting RF signal is amplified and filtered and then applied to an RF mixer.

The other optical signal travels through the fiber optic delay line to its end where a Faraday rotating mirror rotates its polarization 90 degrees from the incident optical signal. This 90 degree rotation of the polarization assures that the reflected optical signs]'s polarization will be at right angles to the polarization of the forward optical signal at the polarizing beam splitter. Since the polarizations of the forward and reflected optical signals are at right angles at the polarizing beam splitter the reflected signal will not pass through the splitter but will be reflected to the photodetector.

The two signals from the photodetectors arc applied to an RF mixer whose resulting output signal is the difference between the delay line's input frequency and its output frequency. This difference frequency signal and the signal from a reference frequency generator are applied to a phase detector resulting in a DC error voltage at its output .

This error voltage is added to the voltage from the ramp generator and the resultant voltage is applied, through a tracking filter, to the voltage controlled oscillator. The error voltage forces the swept frequency to change precisely at the constant rate required to make the frequency difference across the delay 1 ine equal to the frequency of the reference generator.

Conclusion

We have described a technique using an optical delay line to generate an extremely linear frequency sweep over a very wide frequency range. The swept signals can be at RF, microwave, or optical frequencies. The signals thus generated can be used in many applications including Synthetic aperture radar, frequency domain reflectometers, optical metrology systems, and precise d istance measurement systems.

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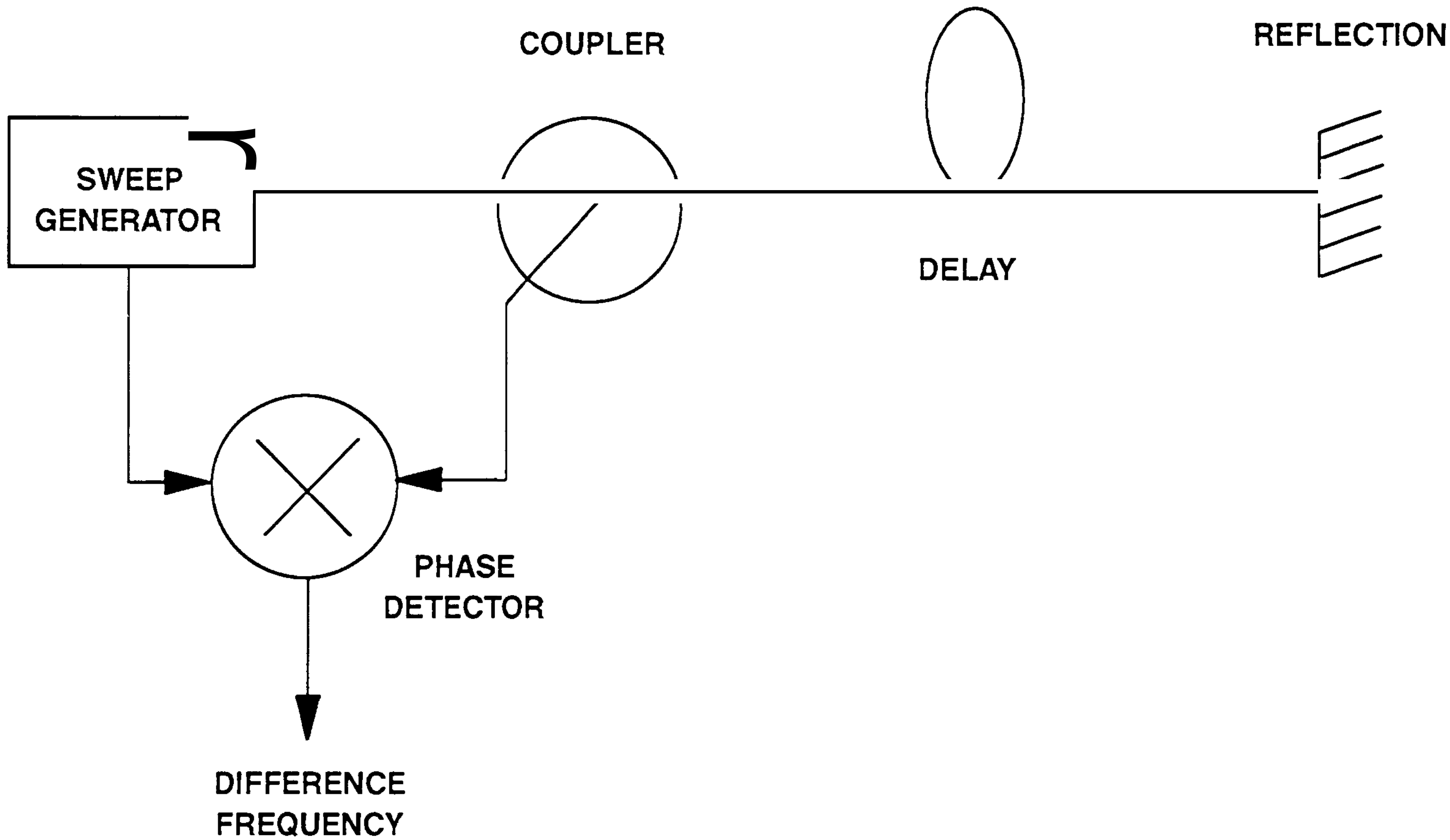

Fig. 1 - Block diagram of a basic FMCW system.

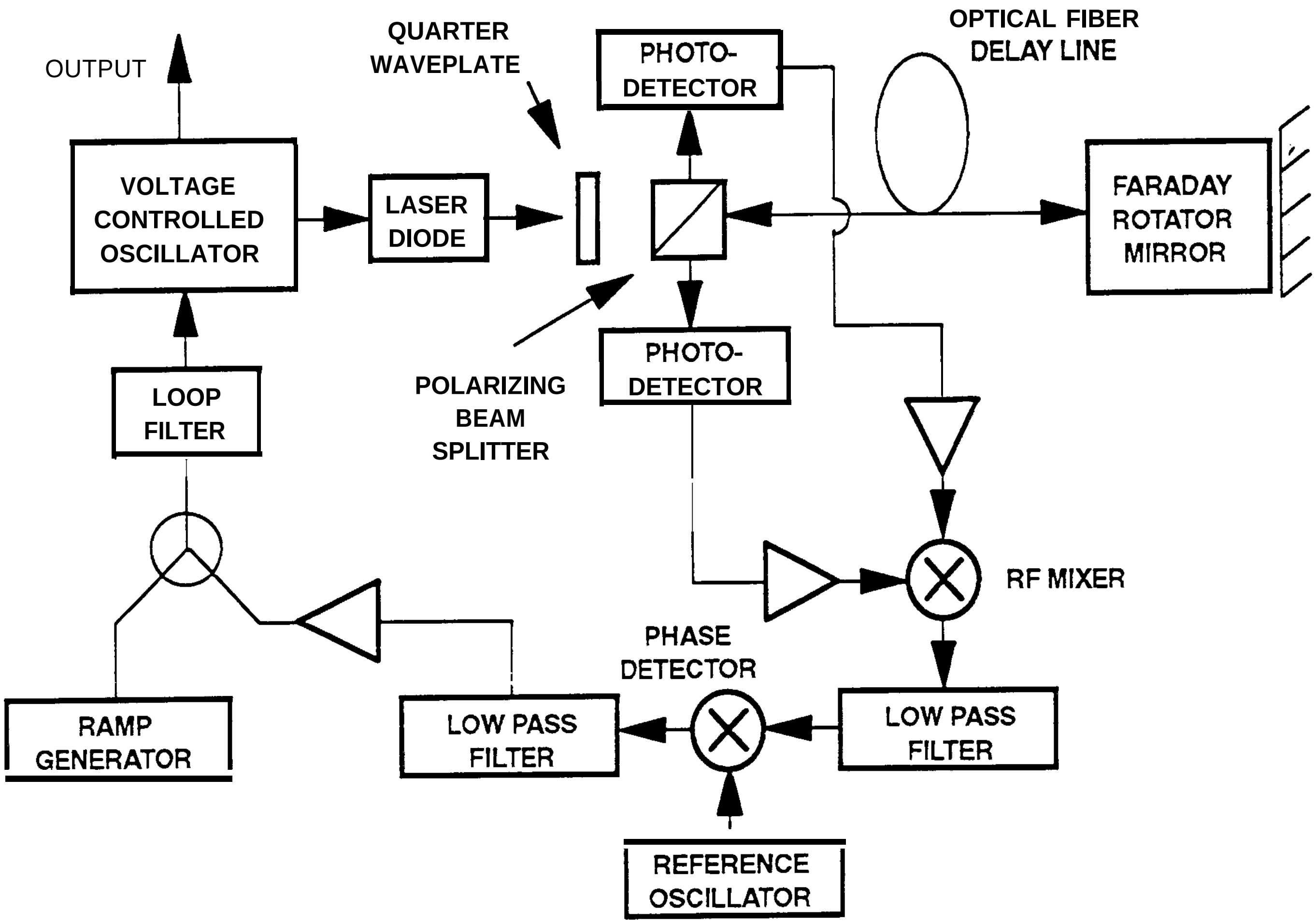

Fig. 2- Block diagram of a linear swept frequency generator.