Interferometer for Co-operating Target Motion Detection

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Abstract—**A correlation interferometer working with a co-operation target operating at 2.2GHz center frequency is presented. This simplified interferometer presented here uses a lock-in amplifier to significantly increase system sensitivity when used in conjunction with a co-operating target signaling using amplitude modulation. The system is verified by detecting the angular velocity of passing tagged target. Experimental results show detectable range up over 110 meters in a multipath environment using a 10dBm EIRP tag.**

Index Terms—**correlation interferometer, object detection, co-operating target.**

I. INTRODUCTION

Object detection has been investigated for diverse applications including safety and security services. Conventional methods such as Doppler radar [1], acoustic transducers, or infrared sensors can detect moving objects. Recently, the correlation radiometer theory has been developed and applied for the detection of self-luminous objects at close range [2]. In this paper we extend its use to the detection of a co-operating low EIRP active target. A demonstration system is constructed for 2.2GHz operation using readily available COTs parts.

The correlation radiometer system [2] employs two antenna receiver systems. The outputs of the two systems correlate through multiplication and integration, responding to the coherence of the radiation detected by the antennas. The geometrical time delay of signal reception between the two antennas produces an oscillating pattern, whose phase variation produces the main correlation frequency response, called the fringe frequency, [2]. As a moving object passes through the systems interferometer fringe pattern the fringe frequency response produces an amplitude response at the oscilloscope in Fig.1, which is proportional to the angular velocity of the objects relative motion with respect to that of the platform on which the interferometer is mounted.

Compared with conventional methods, the signal output of the radiometer is a low frequency time-dependent signal, which is easily processed. In addition the system allows the velocity of targets moving tangentially to it to be determined. This is not possible with a conventional Doppler system, [3].

II. CORRELATION INTERFEROMETER WORKING WITH CO-OPERATING TARGET

The co-operating target used here consists of a battery powered voltage controlled oscillator (VCO) directly coupled to a microstrip antenna array. The VCO has its power modulated through direct d.c. bias control. This produces an amplitude modulated signal, some residual frequency modulation also occurs but this is rejected by the detection system lock-in amplifier. The use of a lock-in amplifier is additionally beneficial for increasing the system sensitivity since lock-in amplifiers [4] can extract the signal with a known reference frequency f_0 from an extremely noisy environment by rejecting noise signals at frequencies other than f_0.

A. Correlation Interferometer

The diagram of the modified correlation interferometer is shown in Fig. 1. The interferometer consists of two identical antenna receivers, operating at an RF center frequency of 2.2GHz. Each receiver circuit contains low-noise amplifiers (LNA), RF2374 and a bandpass filter (BPF), B7750. The outputs of two receivers are multiplied through a mixer and then detected by a lock-in amplifier, HP3581A whose reference frequency set at 1 KHz. Finally the output signal is low pass filtered and displayed through an oscilloscope.
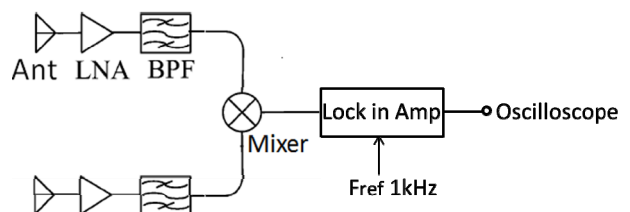

Fig. 1.   Block diagram of the correlation interferometer

B. Co-operating Target

The co-operating target was designed to transmit RF signal at 2.2GHz and is modulated by an f_0 of 1 KHz, the selected reference frequency of the lock-in amplifier.

A Mini-circuit ZX95 VCO is used, whose output frequency is selected by its tuning voltage V_{tune} (in this paper this is fixed) and whose output power amplitude is controlled by its d.c. operating voltage, V_{cc}, as shown in Fig. 2. From Fig. 2, we select an input V_{cc} of 3v peak to peak and applied it as a 1 kHz square waveforms with 7v DC offset (V_{tune} fixed at 11.4v d.c.) signal. The resulting detected VCO output signal displayed on an oscilloscope is shown in Fig. 3 (b). The scheme of the co-operating target is shown in Fig. 3 (a). A 555 timer is used to generate a 3VPP @ 1 KHz square waveform, which sums with 7v DC signal through an operational amplifier (OP_AMP). A 50 ohm input microstrip patch antenna operating at 2.2GHz was also designed and directed connected to the 50 ohm output of the VCO. The prototype of the co-operation target is shown in Fig. 4.
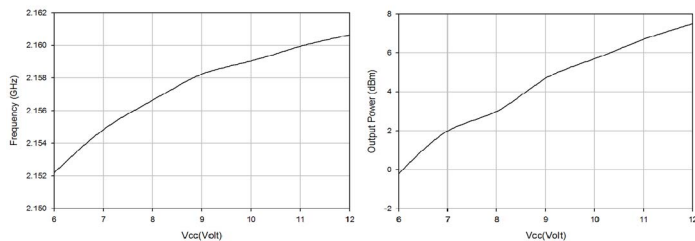

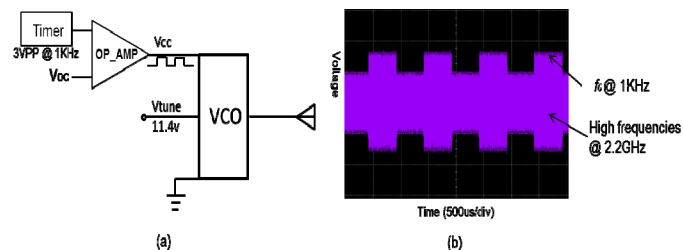Fig. 2. Measured output frequency and power of the VCO with V_{tune} of 11.4v d.c.

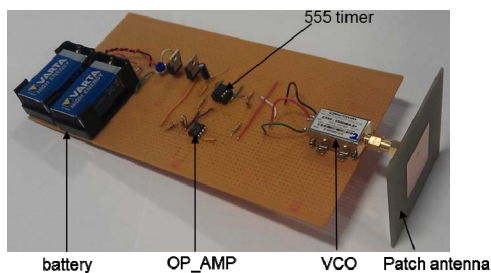Fig. 3. (a) Scheme of the cooperation target (b) output signal shown in oscilloscope

Fig. 4. Prototype of the cooperation target

III. EXPERIMENTAL EVALUATION

To verify the system, experiments were set up to detect the angular velocity of passing targets in a multipath rich office environment, as shown in Fig. 5. The system uses two 4 element patch array antennas with half power beamwidth of 14°, gain 7.5dBi and operating at an RF center frequency of 2.2GHz. The LNAs provides 24dB of gain with a noise figure of 3dB. The lock-in amplifier improves the system sensitivity with the detectable received signal down to -70dBm.

Fig. 5. Measurement setup and test area

Multiple tests were taken of the moving target passing tangentially the interferometer; no attempt was made to polarization match the single microstrip patch antenna on the target (tag) to that of the receiver. The test results are summarized in Table 1. The detected frequencies acquired are similar to the theoretical data predicted using equation (1) [5], where D is baseline of the antenna separation, v is the object's linear velocity tangential to the broadside direction of the sensor, and r is the range between the object and the sensor. Fig. 6 shows screenshots of a typical A.M. response onto which the lock-in amplifier is tracking. The reference frequency f_0 is the 1 KHz modulation superimposed on the returned tag carrier signal. The time base of the oscilloscope is synchronized to the frequency sweep of the lock in amplifier (975 Hz to 1025Hz) in order to allow for the target induced motion that is translated through the interferometer fringe to be observed. In Fig. 6(a) the target is stationary, hence only baseband signal f_0 is detected. As the target moves, both an upper sideband signal, $f_0 + f_F$, and a lower sideband signal, $f_0 - f_F$, appear as shown in Fig. 6 (b). The frequency offset between f_0 and either sideband represents the detected frequency of target as it traverses the fringe pattern, and which itself is a measure of the speed of the target as determined by (1).

$$f_F = vD / \lambda_c\, r \qquad (1)$$

TABLE I.   AVERAGE EXPERIMENTAL RESULTS FOR TARGET AT 6 M/S

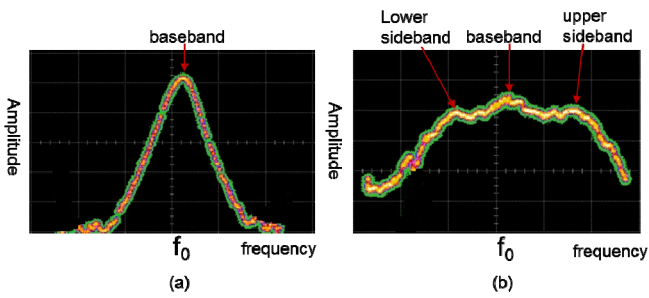| Baseline Antenna Separation	Range (m)	Velocity (m/s)	Detected frequency	Predicted frequency
$8.6\lambda_c$	3.6	6m/s	11Hz	14.3Hz
$8.6\lambda_c$	5	6m/s	8Hz	10.3Hz

Fig. 6. Experimental data examples of A.M. response for (a) stationary object (b) moving object

The detected target velocity of 6m/sec is representative of the speed at which the arms of a man target swing at brisk waking pace. At a range of 3 meters, the target signal is still detectable even after adding 26dB of attenuation. This result indicates that the test range can be extended out to at least 110 meters.

IV. CONCLUSIONS

We have shown a correlation interferometer operating at 2.2GHz with co-operating target and lock-in amplifier leads to a long range operation >100m with low EIRP even in multipath environment. The system demonstrated should find application in propagation hostile environments where stand-off tracking is required at low cost.

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