Distance Estimation with FM-radar using Phase Information

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INTRODUCTION

A technique for distance estimation with Frequency Modulated radar is proposed. In this method is utilized interference between the transmitted signal and local reference. In [1] is presented a method for vibration measurement with FM-CW radar. Here the principle is developed further to enable peer-to-peer distance measurement.

VIBRATION MEASUREMENT WITH FM RADAR

In the radar for vibration measurement [1] is used a feedback circuitry to keep the system on balance.
The frequency modulated signal sent by the transmitter Tx is

$$f = f_0 + \Delta f \cdot \sin(2\pi f_m \cdot t) \qquad (1)$$

Where

f_0 is center frequency
Δf is deviation
f_m is modulation frequency.

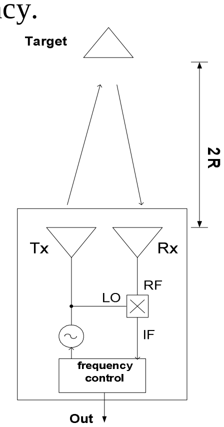

Figure 1: Vibration measurement with a monostatic FM-CW radar [1].

The center frequency ‘f_0 ‘ and deviation ‘Δf ‘ are chosen so, that at the upper frequency ($f_0 + \Delta f$) the phase of the reflected signal is the same as the transmitted signal and at the lower frequency ($f_0 - \Delta f$) the phase is opposite. A symmetrical signal at the modulation frequency (f_m) is obtained. Change in the distance changes the phase relationship and causes asymmetry in the output. This can be utilized to measure the target movement and vibration. Here the distance must be known.

DISTANCE ESTIMATION WITH FM RADAR

The same principle can be developed further to estimate also the distance. When the center frequency is proper versus the distance, the lower and higher frequencies are out of phase at the receiver. Condition for this is:

$$R = n\,\lambda_{low} = (n + ½)\,\lambda_{high} \quad \text{or} \qquad (2)$$

$$R = (n - ½)\,\lambda_{low} = n\,\lambda_{high} \qquad (3)$$

The deviation (Δf) and the center frequency (f_0) can be utilized to estimate the distance.

DEVIATION

The output signal has the maximum value at 180 degrees phase difference. If the deviation is raised more the mixer output is distorted. Thus the deviation with maximum undistorted output can be used to estimate the distance:

$$R = c / 4\Delta f \qquad (4)$$

The required deviation is inversely proportional to the distance, which is not very applicable with indoor positioning applications.

CENTER FREQUENCY

Also the center frequency (f_0) affects to the output signal symmetry. Equations (2) and (3) determine the frequencies, where the receiver output is symmetrical at a given range. These frequencies occur at n values 0.5. At consecutive frequencies f_{01}, f_{02} and f_{03} we have

$$R = n \cdot c / (f_{01} - \Delta f) = (n+0.5) \cdot c / (f_{02} - \Delta f) = (n+1) \cdot c / (f_{03} - \Delta f). \qquad (5)$$

From (5) the distance can be estimated:

$$R = c / 2(f_{02} - f_{01}) = c / (f_{03} - f_{01}) \qquad (6)$$

Laboratory measurements and simulations show, that the distance can be determined according to (4) and (6). In this study was used the same source for Rx and Tx. Thus there was no phase nor frequency error. However the basic idea for distance estimation with FM-radar using phase information is valid.

Reference

[1] M. Tiuri and J. Hyyryläinen, “Microwave Radar for Measuring Vibrations on Power Transmission Lines,” *Conference proceedings of the 13th European microwave conference*, Pages 663-666, Nurnberg, West-Germany, 1983.