Microwave Gauging with Improved Angular Resolution

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***Abstract*— Angular resolution of a microwave level gauge may have positive impact on the robustness of the target detection. Therefore, an azimuthal scan can be performed with the aid of electronical or mechanical beam-steering methods. The present paper provides an overview and a comparison of signal-processing methods which improve the angular resolution of such measurements. For a given antenna, improvements can be achieved well beyond the limit of the half-power beam-width (HPBW) of that sensor. Among others, the performance of the Wiener filter and the Kalman filter for a motion-free channel is examined in greater detail since their application exhibits promising improvements on the angular resolution in both, simulations and measurements. In addition, the advantage of using a Kalman filter for a channel with statistical fluctuations is shown in simulations.**

I. Introduction

Among the civil applications of radar, one of the most important ones, is industrial level gauging. In most cases, the microwave level gauge is a monostatic radar system. The radar is mounted on top of a reservoir and determines the delay of a wave which is reflected by the tank level. In addition to the *interesting target* level, many *jam targets* such as metallic fixtures with a large variety of reflectivity will occur within the channel. An abstracted gauging setup is shown in Fig. 1. Due to limitations of size and cost, the directivity of the antenna is limited. Hence, jam targets appear in the impulse response (IR). An appropriate algorithm (e.g. [1]) can be used to separate the impulse response in terms of the gauging level and jam targets.

A number of practical problems arise when this separation fails. In order to improve this separation, beam steering is investigated. Even though, in practical applications electronical beam steering will be preferred, we concentrate on a method which applies mechanical beam steering in the first place.

Imagine a rotating antenna – the occurring mathematical operation can be described as a convolution of the beam pattern $h_{ant}(\varphi)$ and the underlying scene of targets $x_s(\varphi)$ over azimuth φ [2]. The output of such a system $y_s(\varphi)$ is described by the well-known convolution expression in Eq. (1) inside integral limits $[-\pi, +\pi]$, founded by periodicity of azimuth φ.

$$y_s(\varphi) = \int_{-\pi}^{+\pi} h_{ant}(\varphi - \tilde{\varphi}) \cdot x_s(\tilde{\varphi}) \, \mathrm{d}\tilde{\varphi} \qquad (1)$$

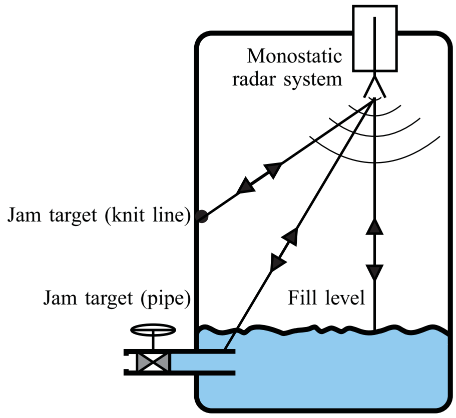

Fig. 1. Abstracted microwave level gauge.

In the following a short form of Eq. (1) is used by spending the convolution operator $\overset{\mathcal{D}}{*}$, in which $\mathcal{D}$ explicitly denotes the actual dimension(s) to convolute. Therefore Eq. (1) can be written in the following way:

$$y_s(\varphi) = h_{ant}(\varphi) \overset{\varphi}{*} x_s(\varphi) \ . \qquad (2)$$

It must be pointed out that the beam pattern $h_{ant}(\varphi)$ incorporates the directional behavior of the used antenna twice: transmitting and receiving path; each time influenced by the antenna.

II. Channel Model

Before defining the underlying channel model, the influence of free-space loss in wave propagation is excluded to achieve more clear expressions.

According to the target scene $x_s(\varphi)$ in Eq. (1) the expression is extended to a radial dimension r. Consequently, $x_s(r,\varphi)$ contains all targets in a two-dimensional space which can be expressed by assumption of ideal point-scatterers as:

$$x_s(r,\varphi) = \sum_{\nu} \sqrt{\sigma_\nu} \cdot \delta(r - r_\nu, \varphi - \varphi_\nu) \ , \qquad (3)$$

in which σ_ν represents radar cross section (RCS), r_ν radial- and φ_ν azimuthal-position of each target; the symbol $\delta(r,\varphi)$ is the two-dimensional Dirac Delta Function.

Regarding both dimensions, the channel stimulus $x_s(r,\varphi)$ contains no distortion and in consequence potential modifications have to be assigned to a channel impulse response.