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# Requirements on the Dynamics of Site-specific Application Technology

*Farm machinery for site-specific cultivation of heterogeneous populations requires a much higher operational dynamic than for non-site specific plant cultivation systems. Starting with general considerations about site-specific application dynamics, this article considers the specific parameter site resolution, delay time and limiting frequency. The specific parameters were investigated on machinery, including a pendulum meter and a centrifugal fertiliser spreader. This article describes the measuring procedures and results attained from the system pendulum meter and fertiliser spreader.*

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## Keywords

Site-specific cultivation, application technology, pendulum-meter, delay time, limiting frequency

Site-specific plant cultivation requires the site related collection of plant properties such as the fertilisation, plant protection or the yield. The necessary site resolution is postulated in [1] as a raster of 1 m, usually with the same resolution in drive direction and crosswise to the drive direction. Different assessments use the working width of their agricultural machines or a part of the working width as necessary site resolution.

Usually it is possible to achieve a high site resolution with sensors in the drive direction, depending on the drive speed. Crosswise the drive direction more than 1 sensor can be used that is fixed mounted, that leads to considerable amounts of sensor. Another solution is a mechanical scanning device with a moving sensor. A third approach is the extrapolation of one sensor value to the whole working width of the agricultural machine system. This approach is useful, if the sensor value is sufficiently representative for the whole working width and the farm machinery has only a limited ability to change the distribution crosswise, as in the case of a centrifugal fertiliser spreader.

For general statements this article uses the values 1 m, 3 m and 6 m as necessary site resolution, irrespective of the explicit technical solution. Starting from the values for the desired site resolution we can derive the measuring speed for the data collection. After that the whole control system of the site-specific application technology is investigated using the parameters time delay and limiting frequency.

### Requirements for the sample rate

By driving through a heterogeneous canopy population the measured values, e.g. the plant mass, are transformed to time related values by the speed of the farm machinery. The tractor job computer delivers a clock signal about the travelled distance to the data collection system, to give an assignment between measured values and time. Generally the sensor signals are collected with a constant time rate and are digitalised with a constant sample rate.

The accuracy of a heterogeneous canopy population measurement follows from the sample rate of the equipment and the site resolution. The relationship between these parameters can be achieved by using Nyquists sampling theorem. In general the measurement of the highest signal frequency needs a minimum sample rate of 2 samples per time period [2]. Equation 1 is derived from the sampling theorem and calculates the minimum sample rate from driving speed and site resolution. *Table 1* shows some values of minimum sample rates.

$$\text{Sample rate} \geq 2 \cdot \text{drive speed} / \text{site resolution} \qquad (1)$$

In the technical realisation one sensor can be connected to one measuring channel or multiple sensors are time shared on one channel. If n sensors are time-shared on one measuring channel the sample rate has to be increased by a factor of n to observe the condition of formula 1. The amount of data is the same for both technical realisations.

### Application example pendulum-meter and centrifugal fertiliser spreader

The pendulum-meter [3], developed at the Leibnitz-Institute for Agricultural Engineering Bornim (ATB), generates an electrical signal by a special potentiometer. This signal is amplified inside the pendulum job computer and digitalised with a fixed sample rate. The pendulum data are processed online, e.g. starting from the minimum and maximum achievable fertilising values and the actual pendulum angle the process data for the spreader job computer are calculated. In conjunction with the plant mass, a correlated fertiliser mass is achieved via a selected application function. The value for the fertiliser mass is transferred via the bus system to the spreader job computer. Here the sliders control the amount of fertiliser and the fertiliser amount is adjusted accordingly to the pendulum angle.

Special data collection hardware for the tractor was necessary in order to investigate the working dynamic of the whole system. The special data collection system is not necessary for the practical application of the

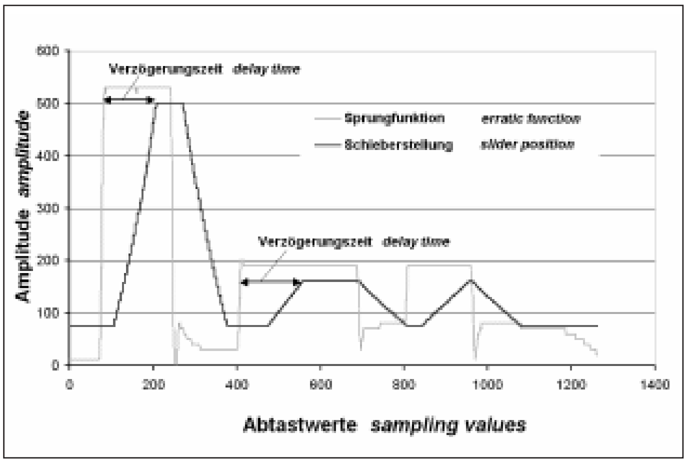


*Fig. 1: Delay time measurement*

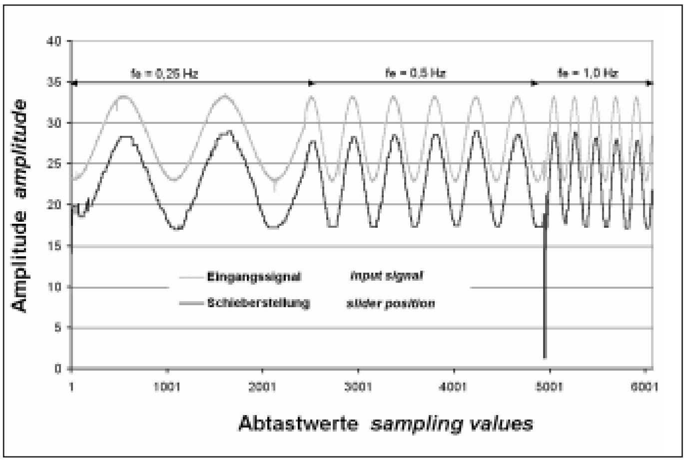


*Fig. 2: Limiting frequency measurement*

pendulum-meter and spreader, but it was necessary to install that data system for the investigation of the working dynamic.[1]

#### Requirements for the dynamic of the system pendulum-meter and fertiliser spreader

The task was to measure the site resolution of the machinery pendulum-meter & fertiliser spreader at different speeds and to check the loading of spreader mechanic due to a fast measuring system. Two different methods were necessary to determine the working dynamic of the investigated system. The first method feeds erratic signals to the input of the investigated system and evaluates the time delay between input and output signal. The other procedure feeds sinusoidal signals with a variable frequency to the input of the investigated system and evaluates the amplitude of the output signal in relation to relative amplitude. This is equivalent to the measurement of the limiting frequency of a system.

*Measurement of the time delay*

A path sensor was mounted together with one of the sliders inside of the fertiliser spreader to measure the course of the slider movements under real conditions. To measure the time delay of the whole system, the pendulum-meter was quickly displaced for a predefined distance and the position changes of the slider inside the spreader were recorded. *Figure 1* shows the courses of pendulum angle and the slider position inside the fertiliser spreader. The time delays due to the end values of the sliders are also calculated here.

The time delays between pendulum angle and slider position result from the difference of the measurement position to the fertiliser application position. The calculated amount of fertiliser can only be placed on the right position, if the working length of the farm machinery is exactly compensated by an appropriate time delay in the signal chain.

[1] The technical solution was developed together with the company Müller-Elektronik in Salzkotten.

If the fertiliser spreader is used under offline control (spreader is controlled by data from a chip card), a time delay is also necessary. The reason is now the partition between the GPS antenna position and the fertiliser application position [5].

The pendulum meter is mounted in front of the investigated farm machinery and the application position of the spreader lies 18 m behind the machinery. The length of the tractor is 7 m and the entire length of the farm machinery is 25 m. It is necessary to realise a speed depending time delay between input and output signals inside of the signal chain to bring the working length of all of the machinery into consideration:

Time delay = working length / speed (2)

A time delay of 5 seconds between the pendulum signal and the output signal (slider position of the spreader) is necessary for the maximum speed of 5 m/s. [5]

*Measurement of the limiting frequency*

The limiting frequency of the investigated farm machinery is the frequency value, where the amplitude of the output signal is dropped to 0,71 of the relative amplitude. The amplitude measured by a frequency of 0,01 Hz is used as the relative amplitude. A digital frequency generator was used as the signal source. The generator feeds sinusoidal input signals into the system instead of the pendulum meter. The courses of the input and output signal for three selected frequencies are shown in *Fig. 2*.

To avoid amplitude errors due to a slow measuring system, it is usual to have a limiting frequency of the measuring system that is ten times greater than the highest signal frequency [6]. The investigated farm machinery has to measure a highest signal frequency of 2,5 Hz, which appears at a working speed of 5 m/s. The tests with limiting frequencies above 2 Hz showed, that such high limiting frequencies leads to a restless working system and a high loading of the slider motors inside the fertiliser spreader. The reason for the distortions and the restless state are vibrations of the tractor, resulting in oscillations of the pendulum-meter. An additional problem is well known from many tasks with the pendulum-meter: The differences in stalk structures lead to pendulum signals above 2 Hz. To suppress the distortions to an acceptable level it was necessary to find a compromise for the limiting frequency of the farm machinery.

At the end of the investigations a limiting frequency of 1,6 Hz was derived from practical tests. This value is sufficient for a site resolution of about 3 m by a tractor speed of 5 m/s. Speeds below 2 m/s are sufficient for a site resolution of 1 m.

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*Table 1: Values of minimum sample rates for different site resolution and driving speed*

| Driving speed | 2 m/s | 3 m/s | 4 m/s | 5 m/s | 6 m/s |
|---|---|---|---|---|---|
| Site resolution = 1m | 4 | 6 | 8 | 10 | 12 |
| Site resolution = 3m | 1,33 | 2 | 2,67 | 3,33 | 4 |
| Site resolution = 6m | 0,67 | 1 | 1,33 | 1,67 | 2 |