Microwave Moisture Measurement Based on the Resonator Method

By TEWS Elektronik

Introduction

A basic aspect of product quality is the moisture content of the material. For optimization of energy consumption and ecological digestibility of the production process in many cases the knowledge of the water content of the product is essential. Only a fast and accurate moisture measurement system for on-line or laboratory application realizes a constantly high product quality using lowest expenditure.

The microwave moisture-measurement units presented in this paper accomplish the requirements of an accurate, fast and simple to operate moisture measurement.

The Microwave Measurement Method

The microwave moisture measurement method reacts with high accuracy to the water molecules in the product. This selectivity results on two attributes of the water molecules:

1. Water molecules possess a strong electrical dipole field which shows a good measurable effect to an external electrical measuring field.
2. Water molecules are very small and movable, much smaller than e.g. sugar-or fat-molecules.

The introduced microwave measuring system produces an external, processor controlled electrical measuring field with very low electrical power and an extremely high polarity changing rate at the sample applicator. This change of polarity takes place with a frequency in the lower gigahertz-range i.e. more than 1000 million times per second and a wavelength of about 10 cm which explicates the general terminus ‘microwave technology’.

If now a sample is placed into this microwave field, the bipolar water molecules orientates with the oscillating external field and begin rotating. Bigger molecules or e.g. ions of mineral salt are not small enough to follow the high rotation rate of the water molecules. The rotating of the molecules with the oscillating external field influences the external field itself in a measurable way.

The practical realization of the microwave method is based upon the resonator method. The low power measuring field (max. 10 mW) resides either inside a metallic cave or upside a plane plate. Due to an extremely exact three-dimensional design of the measuring field there is no ambient emission of electrical energy and no warming up of the product.

Two microwave parameters are measured accurate and fast from the interaction between electrical field and water molecules: energy loss and frequency change of the electrical measuring field. The instrument now determines the result out from the two parameters by means of a patented method. The system registers the complete amount of moisture contained in the sample volume: surface-moisture and capillary bound moisture.

Fig. 1 shows the typical resonance-curve of an empty and filled sample applicator.
Fig. 1: Resonance curves for samples with different moisture content. The diagram shows the received microwave signal over the frequency.

The right peak shows the condition of the electrical field with an empty sample applicator, the left side peaks represent samples with different water content. The more water the sample contains the more flat and left-shifted the corresponding resonance curve occurs.

The patented resonator method of TEWS Electronics measures attenuation and frequency shifting as two separate parameters. By this it is possible to measure the moisture independently from the weight or density of a product.

Fig. 2 demonstrates the principle of the density independent moisture measurement. Frequency shifts and attenuation (increase of bandwidth) of the resonance curves are computed to A- and B-values within a coordinate-system. The point 0/0 represents the empty sample applicator. The measuring values of different samples with constant moisture and varying density causes radial lines through the origin. The angle between the line and the A-axis is proportional to the sample’s moisture content.
System Design in Principle

The microwave moisture measuring system consists of the sample applicator (consists of the resonator, two antennas and cables) and the evaluation unit (consists of the microwave generator, receiver and a solid state computer).
The processor controls the entire measurement and evaluation procedure. All data are stored and statistically prepared for display, printer and data outputs.

**Calibration**

Like all non-direct measuring methods the microwave measuring system has to be calibrated against direct laboratory reference methods like dryer-chamber or Karl-Fischer-Titrator.

The internal calibration software assigns the reference values to the measured microwave values of the same product, computes a regression curve, stores it on solid state disk and shows it in tabular form or graphically on the display. With a simultaneous temperature measurement all fluctuations of temperature are automatically compensated.

All calibrations are long-time stable and can be transferred to other systems of the same type.

Fig. 4 shows the example of a calibration for hop-umbels. This calibration covers 340 samples and figures microwave- and laboratory -values graphically and gives a correlation of $k=0.98$ and a mean deviation of $\pm 0.26\%$ for both measuring methods.
Measurement

For the laboratory version of the microwave measuring system the sample applicator is filled and emptied by hand.

For bulk goods an automatic process system for quasi-continuous measurements in a product by-pass is offered.

Laboratory version

Carrying out of measurements with the TEWS microwave moisture measurement instrument is very simple because of the self-explaining menu-driven software which prevents a faulty operation.

For the measurement the samples are filled into the applicator with a funnel. The standard applicator has a cylindrical aperture with a diameter of approx. 46 mm and a volume of approx. 400 ml. Grinding or weighing of the sample is not required, so bulk goods, granulates, beans or flakes are comfortable measurable. Higher moisture products like pastes or fluids have to be filled into plastic cups before placing inside the applicator.

Here the product is totally covered by the electrical field and so the complete moisture content - not only at the surface - is measured.

Caused by the low microwave power beneath 10 mW no warming-up or any changing of the product happens.

After a measuring time of only a few seconds the measuring results are present and the sample applicator is ready to be emptied.
Process-version

With the process unit fully automated operated and quasi-continuous moisture-measurements directly inside the production process are possible. Offering of the results takes place via analogue or digital interface, so documentation for quality control or controlling of a dryer or other equipment is not a problem.

Administration of the measurement results

All measurement results are presented immediately on the display and will be stored independent of line voltage.

Referring to ISO 9000 the instrument records name, charge number, date and time and remarks in addition to the measuring value.

The statistic software immediately computes mean-, max-, min-values and the standard deviation. The results are displayed alternatively as table or graphics and can be sent to an analogue interface or via the RS232 port to an external personal computer.

Fig. 5 shows the moisture values of potato-protein powder recorded behind a dryer about 6 hours in the production process with a MW 3200.

![Feuchte [%]](image)

*Fig. 5: Moisture in protein-powder, measured moisture values versus number of measurement*

Features of TEWS systems:

- very accurate, high reproducibility
- fast, a complete measurement only lasts a few seconds
- destruction-free measurement, the product does not get changed
- calibrations are long-time-stable and transferable to all TEWS instruments
- automatic compensation of varying product temperature
- measurement is independent of color, structure and other influences to product surface
- results do not change with different weight or density of the product
- very simple handling of samples without weighing or grinding
• results do not change with varying portions of minerals or with product type
• easy combination with other process control equipment
• optimal suitability for quality control referring to ISO 9000

Examples for application

- tobacco and cigarettes
- sulfates, carbonates, nitrates
- hop
- PVC, acrylic glass, various plastics
- coffee, cocoa
- pigments
- marzipan
- fertilizers
- spices
- silicic acid
- grain, flour, noodles, maize
- pharmaceutical granulates, tablets
- milk powder, casein
- vitamins
- soya, rape, sunflowers
- paper, foils, cloths
- feed
- sand, lime, building materials

Assortment of instruments

The **MW 3300** is the standard model for laboratory with a multitude of measurement-, calibration- and evaluation-functions. It is well suited for quality control according to ISO 9000 standard.

The **MW 3200** offers the same features like the MW 3300 but without display and keyboard, it has to be controlled by an external computer. This unit is provided for online applications like controlling of a dryer about analogue and digital interfaces. The sample applicator is installed in a bypass to the product main stream.

The **MW 3150** is designed for manual routine-measurements, it offers a very simple handling without graphical features.

The inline moisture measuring system MW 3260 with planar sensor can be integrated directly into the production process without a bypass or other mechanical support and measures the moisture of the moving product with a penetration up to 10 cm into the product. The planar sensor for example can be mounted between two conveyor belts or on the bottom of a silo.

The **MW 1000** is the new pricey handheld version for routine measurement in bulk materials.

All instruments operate with the uniform measuring-principle. Depending on the application various applicators with sample volumes from 1 ml to 2 litres are available.

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