The MMA-2000
Microwave Moisture Analyzer
for
Industrial Process Monitoring and Control

Fig. 1 The MMA-2000 System

*The MMA-2000 is the most advanced non contacting two-parameter microwave sensor system available for continuous, on line monitoring of industrial material bulk properties such as moisture content (**mc**) and basis weight [mass per unit area]. The system is ideal for monitoring moving panels and bulk granular/particulate materials being transported by a conveyor or shaker, or by gravity flow in a hopper. Advanced features include:*

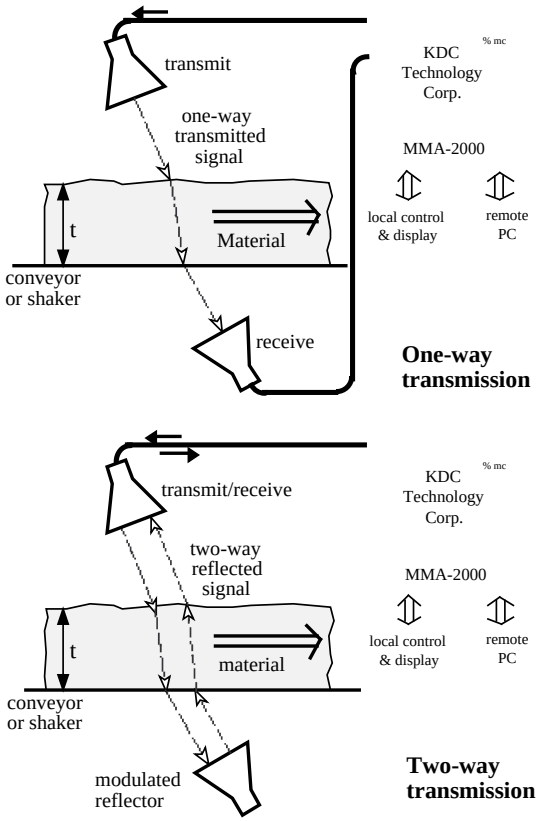
- *Bulk moisture content and basis weight that are measured simultaneously and independently**
- *Non contacting mass transport scale**
- *Compensated for wave reflections at air/material interfaces**
- *One-way, two-way*, or four-way* thru--transmission sensing*
- *Temperature compensation*
- *Microprocessor-based, automatic & user friendly*
- *Computation of complex dielectric properties**
- *Wide dynamic range of material moisture and thickness*
- *Industrialized , user friendly packaging*
- *Environmentally safe*

These features are unique to the MMA-2000

Principles of Operation

The MMA-2000 is a highly sensitive, non contacting, two-parameter instrument in which a beam of low level microwave power is transmitted through a thickness of the test material. Two configurations are depicted below. The two measured parameters are the changes in signal absorption or attenuation (ΔA in dB) and the time or phase delay (Δϕ in deg.) caused by passing the signal through the test material.

Because free water molecules are highly polar at microwave frequencies, water has an exceptionally large dielectric constant (ε') and loss factor (ε"). Consequently, even very small moisture contents have substantial affects on ΔA and Δϕ. But material basis weight (density x thickness) also effects ΔA and Δϕ. Through proprietary algorithms, the measured ΔA and Δϕ are used to determine the bulk moisture content (**mc**) and basis weight (**m**), simultaneously and independently.



Because the received modulated microwave signal must travel through the material twice in the two-way system, the measured changes in attenuation and phase due to the material are

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double those of the one-way system, so the sensitivity to the material properties is also doubled. Otherwise, there is little difference in operational principles between the two systems. The two-way system does have the important advantage that no rf cable is needed for the lower antenna. This simplifies system installation and significantly enhances stability.

Carrying these multiple pass techniques even further, a four-pass system (not shown) is now available. This system is useful for very thick, very low density materials having low **mc**.

Instrumentation

The main electronics unit includes a phase-locked fixed-frequency microwave source, a proprietary receiver, phase and amplitude detectors and logarithmic amplifiers, and a microprocessor. Using proprietary empirical models and stored calibration coefficients, the microprocessor computes, displays and stores **mc** using the measured ΔA and $\Delta\phi$. Since ΔA and $\Delta\phi$ are usually temperature dependent, the material temperature as measured by a temperature sensor is factored into the models.

The instrument is user controllable with a local hand held control/display terminal. The display is user-programmable to show, e.g., time, product temperature, instantaneous **mc** and **m**, and **mc** and **m** that are averaged over a specified time window. Control and data readout also can be via a 4-20 mA analog output, or a digital RS link (optional) to a remote computer. Solid state memory and a floppy drive (optional) store data for back-up or later retrieval.

Basis Weight, Thickness, Density, Moisture Content and Mass Transport

The basis weight (**m**) is the integral of the point function density ($\rho(x)$) through the test material thickness (t), i.e., $\mathbf{m} = \int^{t} \rho(x)dx$ kg/m^2. Since the measured ΔA and $\Delta\varphi$ are also integrals through the thickness, the basis weight can be found without explicit knowledge of either $\rho(x)$ or t. Then, knowing **m,** the effective width (w) of the test material and the velocity (υ) of the conveyor, the rate of mass transport **M** (= $\mathbf{m}\upsilon w$) kg/sec. can be calculated. An important advantage of the MMA-2000 is that it is non contacting, and hence does not alter either the thickness or the density during measurement. This is absolutely essential for measurement of diffuse materials such as fibers or particles.

Calibration

Initial system calibration typically is done at the factory prior to shipment with user-supplied samples of the test material. Calibration fine-tuning and occasional checks of an installed system can be done by taking samples from the production line. Calibration coefficients as well as offsets and slopes of calibration curves are entered or adjusted via the control terminal.

Accuracy, Resolution and Sensitivity

System accuracy and resolution are primarily determined by the standard method used (e.g., loss-on-drying). Standard deviations of **mc** typically range from 0.2 to 0.5%, and the resolution typically ranges from 0.1 to 0.3%. These ranges depend on the granularity, homogeneity, thickness, moisture content, etc., of the test material.

At very low levels the moisture can become electronically bound, non polar and hence generally not detectable. Similarly, at sub-zero temperatures, all water becomes non polar, although this transition occurs substantially below zero ^{o}C for most organic host materials.

Some Applications

The MMA-2000 finds use where non contact and/or high speed measurements are required. Broadly stated, applications include moving panels or bulk granular/particulate materials being transported by a conveyor or shaker, or by gravity flow in a hopper.

Here is a partial list of specific applications:

Wood fibers, particles, flakes, strands, chips, pellets
Wood panels (fiberboard, particleboard, OSB, wetlap. etc.)
Grains, beans, feeds, seeds, meal, nuts
Fibers (cotton, wool, synthetic, glass, wood, etc.)
Minerals (ore, coal, shale, sand, ash, etc.)
Processed Foods (cereals, snacks, flour, powders, etc.)
Dried foods (vegetables, fruits, spices, etc.)
Pulp, forage, silage

Microwave Dielectric and Loss Properties

Although the MMA-2000 computes the moisture content directly from the measured ΔA and $\Delta\phi$, there are numerous instances where the complex dielectric constant (relative permittivity) $\varepsilon^* (= \varepsilon' - j\varepsilon'')$ of the test material is also of interest. The dielectric and loss parameters (ε', ε'') are fundamental to the characterization of materials, e.g., determining the effective (ε', ε'') can be an intermediate step to determining the moisture content. Optional proprietary software is available that computes and displays the *in situ* values of (ε', ε'') in real time. This software requires that the material thickness is known, and it assumes that the material density is homogeneous within the volume of the microwave beam. The software fully accounts for oblique incidence of the microwave beam and for wave reflections at the air/material interfaces.

[1] R.J. King, Ch 11 in Microwave Aquametry, IEEE Press, 1996

[2] R.J. King, Ch 5 in Sensors Update, V7, Wiley-VCH, 2000

Specifications

•Frequency:	Fixed between 3 to 12.5 GHz
•RF Output Power:	< 15 mW
•Antennas:	Linear or Circular Polarized
•Beamspot Diameter:	3 to 30 cm, depending on freq.
•Measured Parameters:	Attenuation (ΔA) and Phase ($\Delta\phi$)
•Data Rate:	20 measurements/sec.
•Accuracy:	$\pm$0.1dB, $\pm$2 deg (See technical description)
•Resolution:	$\pm$0.05dB, $\pm$1 deg (See technical description)
•Control/Display	
-Local :	4 x 20 Char's LCD, Full Keybrd./ 3 1/2 digit panel LED displ.
-Remote PC (option):	RS xxx
-Analog Out:	4-20 mA
•Floppy Drive (option):	3.5", 2HD (1.44 MB)
•CPU Microprocessor:	486/586, w/ 1Mb RAM
•Instrument:	
-Temperature:	0 to 65 ^{o}C (32 to 150 ^{o}F)
-Weight:	15 Kg (33 lbs.) in NEMA Encl.
-Dimensions	20.3 H x 40.6 W x 40.6 L cm (8 x 16 x 16")
•Primary Power:	Std. 110/240 VAC Single Phase, 50W
•Enclosure:	NEMA to User's Specification

Technical Assistance

To learn how this new technology can help you solve your material sensing needs, contact a KDC engineer for immediate attention. At KDC you will find leading sensor technology and engineering solutions backed by strong and dedicated technical support.