Microwave Sensors for Industrial Applications

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Neither of production control systems can do without sources of original information, namely, sensors monitoring the behaviour of process equipment. Push-button-relay control panels are replaced with microprocessor-based process control systems demonstrating the highest performance and reliability characteristics. Sensors are furnished with digital communication interfaces, however, this does not always result in the improvement of the general reliability and veracity of the system operation. It can be explained by the fact that the very principles of operation of the majority of the known sensor types dictate the necessity for active constraints concerning the conditions of sensor application.

The main function of a process control system is in the precise observance of feedstock processing technology and feedstock conversion into end product. In addition to continuous equipment monitoring and prevention of emergency situations a competently designed system must keep track of the product handling within the complete chain of processing machinery.

Technological processes intended for the modification of the chemical composition of feedstock, in-stream blending of various materials, wetting, etc. in case of loss of any component must provide for the reliable cut-off of the rest. Spring-loaded plates with microswitches are still in use for the control of availability of a product flow. In operation they are exposed to continuous shock impacts of humid and aggressive environment that naturally results in "freezing" of contacts or mechanical failure of plates.

Thus, the absence of reliable and cheap sensors for monitoring of industrial machinery and equipment results in the decline of the efficiency of production control systems, and poorer return of funds invested in automation. Sophisticated and expensive process control systems based on conventional types of sensors are only suitable for convenient group switch-on/switch-off of processing circuits, and in many cases they are not able to improve the quality of products and to save feedstock and resources.

The necessity for continuous maintenance, control and adjustment of sensors results in downtime: for the removal of the stuck product from a capacitance sensor it is necessary to discharge a bunker, to prepare and to install a winch for the personnel access to the bunker, on completion of the maintenance process it is necessary to adjust the device; for the replacement of a velocity pick-up or drag-type sensor on a continuous-bucket elevator the complete disassembly of the elevator boot is required. As a rule it takes several hours that brings down the production rate of a facility as a whole.

Several years ago the above mentioned problems gave rise to the development of radically new types of devices, namely, radar velocity pickups, mechanical motion and backup-pressure transducers, which operation is based on the interaction of the controlled item with a nearly $10^{10}$ Hz frequency radio signal.

Application of microwave methods of process equipment monitoring is completely free from the disadvantages of conventional-type sensors. Moreover, new devices successfully eliminate the earlier unsolved problems faced by process engineers and automation departments, as well as control and measuring instruments and automatic equipment sections.
The peculiar features of these devices are as follows;
- absence of a mechanical or electrical contact with an item (medium), the distance between a sensor and an item may be several meters;
- direct monitoring of an item (conveyor belt, chain) itself rather than its drive, tension drum, etc;
- low energy intensity;
- insensitivity to product sticking due to large working distances;
- high interference immunity and precise directivity of operation;
- air-tight design
- once-only tuning for the entire service life;
- high reliability, safety, the device is free from ionizing radiation.

The right part of the table presents a list of microwave sensors for industrial automatics, which are commercially manufactured by the PromRadar research and production company, while the left part reflects the application areas of these devices.

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<tr>
<td>Complete monitoring of product pipelines (bunkers): no product, product flow, backup pressure</td>
<td>RDDP-01</td>
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The RDKS-01 velocity pickup (Patent of the Russian Federation No.219305 of 20 04.98) is intended for the monitoring of a rate of movement or rotation of various industrial machinery, such as, horizontal and inclined conveyors, continuous bucket elevators and other equipment. The main function of the device is to give an alarm signal or to cut off the machinery if its rate of movement (rotation) is beyond the preset range thus preventing an emergency situation.

The device consists of an RDKS-01PP sensor (Fig.1) and a speed relay (Fig.2) connected by an up to 300 m long double-wire circuit.
Through a plastic housing a Doppler receiver-transmitter unit of the sensor emits radio signal to a moving target. If the conveyor moves, alternating voltage appears at the output terminal of the unit, which frequency is proportional to the rate of movement. After preprocessing, a signal is transformed into a short current pulse string which is not exposed to the effect of industrial noise and other interference factors, and enters the speed relay. It is usually installed in an electrical control switchboard room near a starter, and when the rate of machinery is beyond the preset range it either cuts off the machinery or gives an alarm signal.

The above described principle of the RDKS-01 device operation provides for the monitoring of any item irrespective of the type of material it is made of. Therefore the device can be used with such machinery, as continuous bucket elevator with a closed boot, plastic buckets, twinned continuous bucket elevators, etc. Assembly and hookup of the device are easy processes, as, firstly, the RDKS-01PP and RDKS-01RS are connected by two wires, and secondly, the sensor can be installed in any point of the conveyor. It allows the RDKS-01 application instead of old-type sensors and transducers without any need for additional cabling.

The sensor housing is provided with the IP54 protection proved by independent trials that allows the device application in rooms with explosive atmosphere of the BIIA category ( Permit No.02-35/470 issued by the Mine Safety Inspectorate of Russia). Concluding the review of the RDKS-01 device it is worthy of noting that with all its advantages it is not more expensive than other domestically manufactured commercial velocity pickups.

The RDD-02 (Fig.3) and RDD03 (Fig.4) mechanical motion transducers enable the control system to "see" the product passing through the processing machinery, i.e., to control the progress of the technological process from the reception of feedstock to end product output. Controlling the cut-off of unloaded machinery, preventing the product ingress in air ducts of aspiration systems, the mechanical motion transducers provide for actual saving of feedstock and electricity. Besides, they can be used for the monitoring of the motion of airlock gates, chain conveyors and other electrical equipment. For instance, the installation of a motion transducer on a chain conveyor will provide for its instantaneous stopping in case of the chain failure that will allow the company to avoid spending extra funds for repair and rebuilding of the broken equipment.
Product "choking-up" inside the processing machinery can result in its failure, and the only possible way to replace an operator near the watch window is the installation of a motion transducer in the output product line.

The functioning of motion transducers similarly to that of the RDKS-01 velocity pickup is based on Doppler effect, i.e., the moving item excites an electrical signal in the outlet of a microwave receiver-transmitter unit.

The RDD-02 motion indicator is connected directly to 187-242 V alternating current network, with power consumption of at most 2 VA. The housing protection is RDD-02-IP54.

The design of the RDD-03 device allows its installation on product pipelines of a 50-mm diameter. The output stage of the device is a short-circuitproof electronic switch in a load circuit (the supply voltage range from 20 V to 220 V AC/DC, up to 400 mA). The intrinsic power intensity of the device does not exceed 1,5 mA (when switch closed), its working distance is up to 30 cm, water- and dust-proof features are IP65.

Standard-design devices are able to detect the motion within a 0.1 to 25 m/s velocity range. For items moving at a very high speed the upper boundary of the controlled speed can be raised. The device sensitivity is tuned within a broad range allowing the monitoring of the motion of nearly all materials, ranging from metal blades of a fan to dried woodworking wastes. Fig.5 presents an example of an option of the RDD-02 indicator installation on a chain conveyor.

The device is mounted on a conveyor frame structure near the drive head unit. The working distance of the indicator is limited by a sensitivity control in such a way that it reacted upon the motion of the nearer (upper) chain. In case of chain failure in any point, it immediately slacks near the head drive unit leaving the zone of the device operation.
In a similar way it is possible to not only detect the presence and absence of mechanical motion but also to monitor the variation of the distance between a moving item and the place of the device installation. As the signal strength depends on the characteristics of a reflecting item the motion transducers may be used for the detection and signaling on the presence of some articles or materials on a conveyor belt. If it is necessary to fill a reservoir (ranging from a bunker to a pit), it is possible to identify the moment of the completion of filling as follows: the transducer sunk to a certain depth will indicate the motion of a material until the sensor is covered by it. Application areas for microwave motion transducers in various industrial sectors are determined by sector peculiarities, however, in general they are helpful for the handling of various aspects of accident-free operation of equipment and for the improvement of the information content of automatic control systems.

The operation of microwave indicators of level is based on the decline of the radio signal magnitude while passing through a product layer (Fig.6).

![Fig.6 Operation of microwave level indicators](image)

Radio-signal oscillator and detector are installed on opposite sidewalls of an item. When the space between them is filled with a product the voltage amplitude in the detector outlet dramatically declines that results in the response of the transducer to the "backup-pressure effect". Feedstock material sticking to micro-wave assemblies does not affect the device operation – its sensitivity is tuned in such a way that it worked only with complete covering of the detector unit.

The layer of the stuck product of several centimeter thickness is not an obstacle for a radio beam propagation, the device works when the material fills a bunker to the full preset height and width.

For the same reason the device does not react to high dust content inside the bunker, it is insensitive to the product contact with the effective area of sensors in the process of the bunker filling and discharge. The advantages of microwave level indicators are particularly clearly demonstrated in those areas where steaming or hot-air treatment of products are envisaged. In these cases, bunker sidewalls become "overgrown" with the stuck material during the first several minutes of operation, and any other devices are immediately disabled. The device is resistant to temperature difference, the magnitude of the oscillator signal and the device sensitivity are actually constant within a – 40 to +40°C temperature range. Dust and water-proof features of external units of the device are at least IP65 and those of the indicator are IP54.

In most cases, microwave sensors can replace radioisotope indicators of level, which operation requires high costs due to the necessity of payment for repetitive verification tests performed by the Nuclear Safety Inspectorate. Such a replacement allows the company to get rid of potentially critical equipment, moreover, it is economically feasible, as the costs of transition to microwave sensors including the utilization of radioisotope indicators, as a rule, are lower than those of one verification test. Microwave sensors have been successfully used for several years instead of radioisotope indicators with various medium and materials ranging from a grain to metal-bearing ores.
The considerable range of level indicators provides for their application to control the backup pressure in various items, such as, gravity chutes and bunkers of 20 cm to 8 m size. The RSU-1 sensor intended for small-size items has only one outside unit, i.e. a detector, while a radio signal oscillator is a built-in component in the device housing. Fig.7 shows an option of the sensor installation on the head of a continuous bucket elevator, while Fig.8 demonstrates the one on a bunker.

![Fig.7 Backup monitoring in the head of a continuous bucket elevator](image1)

![Fig.8 The product level sensor in a bunker](image2)

The complete monitoring of the process of product going through a material pipeline can be provided by application of the RDDP-01 device. It detects separately the product flow and backup pressure. Thus, the device indicates all the possible processes going inside: the product is not available, the product is moving or the product has already filled the item. The output signals of the device provide, for instance, for the monitoring of the continuous presence of a feedstock flow in a product pipeline including the discharge in case of backup and feeding in case of the product absence. The signal of the flow motion will indicate a normal course of the process.

![Fig.9 Operation of a microwave motion and level sensor](image3)

![Fig.10 Assembly of the RDDP-01 device](image4)
The operation of the microwave motion and backup transducer is illustrated by Fig.9. A Doppler receiver-transmitter unit is mounted inside the indicator housing. With the product movement the frequency of the reflected radio signal differs from that emitted. The frequency difference results in the response of the motion-monitoring channel. A portion of the signal goes through the flow and enters the outside detector. When the item is filled with the product, the voltage amplitude in the receiver will decline resulting in the response of the backup-pressure monitoring channel. The RDDP-01 device provides for the monitoring of items of up to 1.5 m size. Fig.10 shows an option of the device installation on a gravity chute.

Microwave velocity pickups, motion transducers and level indicators for several years have been successfully used by hundreds companies in different sectors. They have unchallengeable advantages as compared with other types of industrial sensors that provides for the improvement of process safety, reduction of the equipment wear, expansion of functional capabilities of automatic production control systems, considerable saving of material and energy resources.