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DEVELOPMENT OF A UNIVERSAL HUMIDITY CONVERTER AT ULTRA HIGH FREQUENCY

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planar lithium niobate waveguide // Electron.Lett, 1(25), 174-175.

5. Ito H., Takyu C., Inaba H. (1991) Fabrication of periodic domain grating in $LiNbO_3$ de electron beam writing for application of nonlinear optical processes // Electron.Lett.,12(27), 1221-1222.

6. V.G. Dmitriev, G.G. Gurzadyan, and D.N. Nikogosyan, (1999).Handbook of Nonlinear Optical Crystals, Springer, Berlin, 400.

7. Fejer M.M., Magel G.A., Jundt D.H., and Byer R.L. (1992).Quasi-Phase-Matched Second Harmonic Generation: Tuning and Tolerances // IEEE. Jour. Of Quantum Electronics, 11(28), 2631-2654.

8. Byer R.L. (1977) Quasi-phase matched nonlinear interactions and devices //J. Nonlinear Optical Physics&Materials,v.6, 549-573.

9. Yusupov D.B. (2005). Generation of Second Optical Harmonics in Crystals with Modulation of Nonlinear Susceptibilities. Uzbek Journal of Physics, 6(7), 503-506.

10. Sapaev U.K., Yusupov D.B. (2023) Backward second harmonic generation in periodically and aperiodically poled quasi-phase matched crystals. Technical science and innovation ,№4,135-149.

11. Yusupov D.B. (2006) On the Theory of the Second Harmonic in Nonlinear Crystals with a Regular Domain Structure. Journal of Laser Physics.- Moscow, **16,** 503-506.

12. Yusupov D.B. (2008) Degenerate Parametric Frequency Conversion of Phase-Modulated Femtosecond Laser Pulses in Crystals with a Regular and Chirped Domain Structure. Journal of Laser Physics.- Moscow, **18**, 43-51.

13. Yusupov D.B. and Chirkin .A.S. (2007) Frequency Doubling of Phase-Modulated Femtosecond Laser Pulses in Periodically Poled and Chirped Nonlinear Crystals. Physics of Wave Phenomena. **15**, 263-271.

14. Sapaev U.K., Yusupov D.B. (2022) Nonlinear pulse compression by consecutive optical parametric amplication in quasi-phase matched structures. Journal Technical science and innovation, 2(4) , 149-154.

15. Юсупов Д.Б., Курбанов Х.Х. (2023) Генерация третьей гармоники в нелинейных фотонных кристаллах. Международный научный журнал «Флагман науки» 4(4), 11-13.

16. Yusupov D.B., Sapaev U.K. (2022) On the Theoretical Analysis of Parametric Amplification of Femtosecond Laser Pulses in Crystals with a Regular Domain Structure. Physics of wave phenomena, 30 (2), 277-282.

DEVELOPMENT OF A UNIVERSAL HUMIDITY CONVERTER AT ULTRA HIGH FREQUENCY

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Abstract: *The article proposes the and principle of operation of a universal primary measuring transducer of humidity at an ultra-high frequency with reciprocating motion along the vertical axis of rotation, which allows increasing the information redundancy of the primary measuring transducer (the influence of inhomogeneities, including humidity in the composition of the material, on the measurement result is averaged). The design of the primary measuring transducer under consideration provides for correction of the moisture measurement result by the mass (density) of the material, which will make it possible to carry out measurements without preliminary weighing the sample. The obtained results of experimental studies for cotton fiber using the moisture meter under consideration indicate a high degree of agreement between the approximating dependence and experimental data in all cases.*

Keywords: *measurements, measurements, ultrahigh frequency method, fibrous and solid bulk materials, universal sensor.*

Annotatsiya: *Maqolada aylanishning vertikal o‘qi bo‘ylab oldinga va orkaga, xamda aylanma harakat kiluvchi o‘ta yuqori chastotali universal birlamchi namlik o‘lchash o‘zgartkichining tuzilishi va ishlash prinsipi taklif qilingan, bu yechim birlamchi o‘lchash o‘zgartkichining kerakli ma’lumotlar axborotlari miqdorini oshirishga imkon beradi (modda tarkibidagi notekisliklar, shu jumladan namliklarning o‘lchash natijasiga ta’siri o‘rtacha kiymatga keltiriladi). Birlamchi o‘lchash o‘zgartkichining karalayotgan konstruksiyasida namlikni o‘lchash natijasiga materialning massasi (zichligi) bo‘yicha tuzatish kiritish ta’minlanadi, bu xolat namunani oldindan tortmasdan o‘lchovlarni amalga oshirishga imkon beradi. Ko‘rib chiqilayotgan namlik o‘lchagichida paxta tolasi misolida*

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olingan eksperimental tadqiqotlar natijalari barcha holatlarda taxminiy bog'liqlik va eksperimental ma'lumotlar o'rtasidagi yuqori darajadagi muvofiqlikni ko'rsatadi.

Tayanch suzlar: *o'lchashlar, o'ta yuqori chastotali usul, tolali va qattiq sochiluvchan materiallar, universal uzgartkich.*

Аннотация: *В статье предложена конструкция и принцип работы* ***универсального*** *первичного измерительного преобразователя влажности на сверхвысокой частоте с возвратно - поступательным движением вдоль вертикальной оси вращения, что позволяет увеличить информационную избыточность первичного измерительного преобразователя (усредняется влияние неоднородностей, в том числе влажности в составе материала на результат измерения). В рассматриваемой конструкции первичного измерительного преобразователя предусмотрена коррекция результата измерения влажности по массе (плотности) материала, что даст возможность, проводит измерения без предварительного взвешивания образца. Полученные результаты экспериментальных исследований для хлопкового волокна на рассматриваемом измерителе влажности свидетельствует о высокой степени соответствия аппроксимирующей зависимости и экспериментальных данных во всех случаях.*

Ключевые слова: *измерения, сверхвысокочастотный метод, волокнистые и твердые сыпучие материалы, универсальный датчик.*

Introduction

The measurement of the characteristics of dispersed materials is one of the key quality parameters, and to address these tasks, it is necessary to improve the management of technological processes by applying modern automation tools and rapid control devices for raw materials, semi-finished products, and final products. One of the main parameters influencing the optimization of technological processes and the quality of the products produced is moisture content. Therefore, the development of moisture meters for dispersed materials is currently of particular importance.

It is known that one of the promising methods for measuring moisture content is the ultra-high frequency method [1-3]. The advantages of ultra-high frequency moisture measurement include the possibility of non-contact measurement. Moisture control using the ultra-high frequency method involves exposing the material under inspection to an alternating electromagnetic wave, where information about the moisture content is represented as a function of two variables - attenuation and phase shift of the electromagnetic wave.

In recent years, ultra-high frequency moisture measurement has seen rapid development. Its theoretical foundations have been deeply developed, and a whole range of ultra-high frequency moisture meters has been created for fibrous, solid, bulk, and liquid materials [4,5,6,7]. The interest of developers in the field of moisture measurement in the ultra-high frequency method is explained by such advantages as the possibility of non-contact measurement of integral moisture, relative simplicity and low cost of equipment, and in some cases, good metrological characteristics. It also has a significantly higher sensitivity to free water in the material than to other components, as well as to its physicochemical properties and structure. However, another important advantage of the ultra-high frequency method, which has received little attention until now, is its versatility.

Research methods and obtained results

The moisture meters developed to date are highly specialized, with developers focusing on specific materials in each case. At the same time, the optimization of the moisture meter's design and structure as a whole is aimed at minimizing measurement errors by selecting the type of sample former and its main parameters [8,9,10].

Our work on finding optimal solutions for the creation of versatile converters has shown the potential of developing a unified series of ultra-high frequency converters that can cover virtually all tasks in moisture measurement for fibrous, solid, solid bulk, and liquid materials [11,12]. In practice, converters can have a unified measuring scheme and several types of primary sample formers.

Measuring chambers (cuvettes) serve to localize ultra-high frequency energy in the controlled material sample and to form the sample in a specific way. When measurements are made in free space, the measuring cuvettes are made of material transparent to the electromagnetic field and primarily serve to form the sample in a certain volume and ensure the necessary measurement conditions.

For free-space measurements, we have developed a cylindrical measuring cuvette design that rotates between transmitting and receiving antennas, allowing for multiple measurements without rearranging the sample [13,14,15,16]. We have proposed a universal ultra-high frequency measuring cuvette with reciprocating motion along the vertical axis of rotation, which allows increasing the information redundancy of the primary measuring converter (the influence of material inhomogeneities on the measurement result is averaged). In addition, it provides moisture measurement result correction based on the material's mass (density), which eliminates the need for sample weighing.

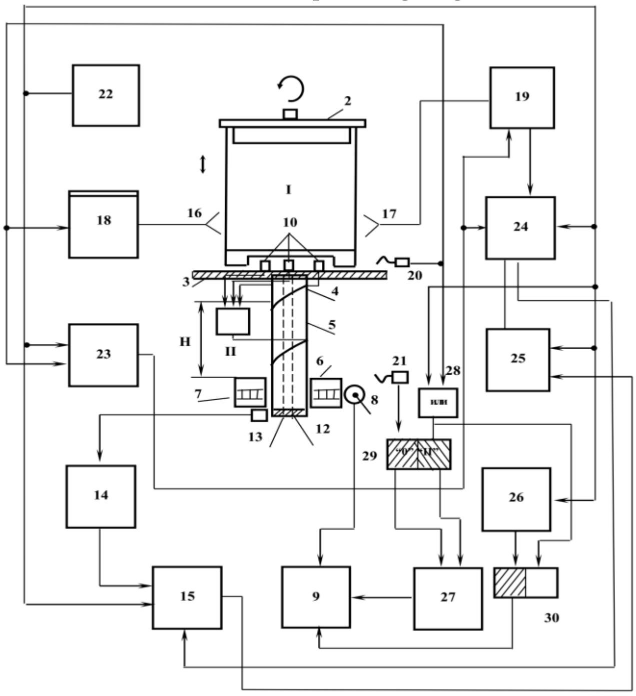

Fig. 1. Primary measuring converter with reciprocating motion and rotation of the sample at ultra-high frequency

Figure 1 shows the design of the proposed universal primary measuring converter. The primary moisture meter consists of a cuvette 1 with a lid 2 for the material under study, a base 3 with a central hole 4, rigidly connected to a screw 5 with a single-threaded screw that is connected to a nut 6, the external surface of which has a rack 7 connected to a gear 8, kinematically connected to a motor 9 with reduction. On the base 3 of the cuvette are force sensors 10 connected through an "AND" coincidence circuit 11 to a collector 12, the signal from which is transmitted by a brush 13 to the input of memory block 14, the output of which is connected to the first input of correction block 15.

The device is equipped with transmitting 16 and receiving 17 ultra-high frequency antennas, which are connected to the ultra-high frequency generator 18 and moisture meter 19, respectively. The elements 20 and 21, corresponding to the upper and lower extreme positions of the cuvette, are located at the top and bottom of the screw 5's movement range. The averaging device 24 is connected by its third input to the device's start element 22, which is connected to the first inputs of the master oscillator 23 and the display block 25, as well as to the second input of the correction block 15 and the time delay element 26.

The moisture meter 19 is connected to the second input of the averaging device 24 for measurement values, the output of which is connected to the correction block 15. The master oscillator 23 is connected to the second input of the moisture meter 19 and simultaneously controls the process of multiple measurements via the first input of the averaging device 24 for measurement values.

The upper position sensor 20 is connected through an "OR" element 28, a single output of the trigger 29, to the second inputs of the master oscillator and the reversal block 27, while the lower position sensor 21 is connected through the zero output of the trigger 29 to the first input of the reversal block.

The primary moisture measuring converter operates as follows. The operator fills cuvette 1 with the sample material without prior weighing and places it on base 3, equipped with force sensors 4 (strain gauges sensitive to pressure on its surface) arranged at 120° relative to each other. Then the cuvette 1 is closed with lid 2 to ensure electrical tightness, dust, and moisture protection from the external environment.

Before starting work, the device is set to its zero position using the start element 22, the ultra-high frequency generator 18 is switched on, and the motor 9 with reduction is activated through the time delay element 26. At this point, the cuvette simultaneously receives rotational and translational motion. Such movement is made possible by the screw 5, connected via a threaded screw with a pitch equal to the movement length of the cuvette with the sample in the vertical direction, i.e., $2\pi = H$, achieved with the help of nut 6, which has a rack 7 on its external surface, kinematically connected to gear 8, located on the motor shaft 9 with reduction.

Control pulses with a constant preset frequency F, synchronizing multiple measurements taken by the moisture meter 19 per one revolution of the cuvette as it moves vertically over height H, are sent to the second input of the moisture meter 19. The n-th number of sample moisture measurements, as a result of ultra-high frequency energy passing from the transmitting antenna 16 through the material to the receiving antenna 17, attenuates the signal amplitude and changes its phase, which is transmitted to the second input of the averaging device 24.

The moisture values Wt are controlled by the master oscillator 23 via its first input. After one cuvette revolution and corresponding downward movement over H = 2, during which n/2 measurements are taken by the moisture meter 19 following commands from the master oscillator 23, the base 3 triggers the lower position sensor 21, which activates the reverse motion of motor 9 with reduction via the first input of the reversal block 27, the second input of which is connected to the upper position sensor 20.

Upon reaching the lower extreme cuvette position, collector 12 connected to the force sensor 10 makes contact with the electric brush 13, which transmits the sample's weight signal through memory block 14 to the first input of the correction block 15 by density, as p = V/m at constant volume V = const and known sample mass m. The output signal of the correction block by density is controlled by the third input of the averaging device to correct the obtained result W_i, taking into account the measurement error. After reversing the motor 9 with reduction, the nut 6 rotates in reverse, raising the screw 5 and the cuvette 1. During the upward movement of the cuvette with the sample, moisture measurement continues following the commands from the master oscillator at the same frequency f, and the results of each measurement are recorded in the averaging device 24.

Thus, another n/2 measurements of moisture are performed during the second rotation. Upon reaching the upper extreme position with the base, the upper position element 20 of the cuvette is activated, which turns off the ultra-high frequency generator 18 and the master oscillator 23, as well as switches the reversal block 27 through its second input to reverse the motor's operation via the "OR" element and the single input of the first trigger 29 with separate inputs.

At this point, the signal from the upper position sensor of the cuvette is sent to the second input of the "OR" element 28, to the first input of which the start command is given at the beginning of the device's operation. From the output of this element, the second trigger 30 with separate inputs is reset to its initial state through its zero input, while the single input of the trigger receives a command from the time delay element 26 to start motor 9, allowing its operation in forward and reverse directions, i.e., for the movement of the cuvette up and down. The reverse rotation of the motor 9 with reduction results in the deactivation of the lower position sensor 21 of the cuvette through the first input of the reversal block 27 via the zero input of the first trigger 29 with separate inputs.

Conclusion

For example, the experimental studies conducted on cotton fiber using the discussed ultra-high frequency moisture meter for materials provided the following regression equations at a sample density of p = 160 kg/m³:

$$W = -1{,}287 \cdot 10^{-2} A^2 + 1{,}108 A - 9{,}52$$

They are approximated by a second-order regression equation. The value of the latter indicates a high degree of correspondence between the approximating dependence and the experimental data in all cases. The considered moisture meter can be used for various fibrous and bulk materials in the agro-industrial, mining, and processing industries of the national economy.

References:

1. Sekanov, Y.P., Lisovsky, V.V. Theory and Practice of Super-High-Frequency Moisture Control of Agricultural Materials. Minsk, 2005. 320 p. (in Rus.)
2. Saitov, R.I. Microwave Moisture Measurement of Agricultural Products. Ufa: "Gilem", 2009. 127 p. (in Rus.)
3. Ismatullaev, P.R., Usmanova, Kh.A., Turgunbaev, A. Moisture Measurement of Cotton and Cotton Materials: Monograph. Tashkent: "Fan va Texnologiyalar", 2017. 262 p. (in Rus.)
4. Usmanova, Kh.A., et al. Final Report on Grant GKNT EF-2-9: Development of Theoretical Foundations for Designing Primary Measuring Transducers with Microprocessor Sets for Quality Control of Various Products. Tashkent: TashGTU, 2017. 148 p. (in Rus.)
5. Sartoros. Moisture Measurement. Theoretical Foundations. [Online]. Available: www.sartoros.ru. (in Rus.)
6. Usmanova, Kh.A., Ismatullaev, P.R. Ensuring Measurement Uniformity of Moisture by Super-High-Frequency Moisture Measurement Method of Solid, Bulk, and Fibrous Materials.Measurement Technology Journal. Supplement "Metrology", No. 4, Moscow, 2016. (in Rus.)
7. Sovlat. Microwave and Super-High-Frequency Moisture Meters. [Online]. Available: info@sovlat.ru. (in Rus.)
8. Usmanova, Kh.A., Turgunbaev, A. Super-High-Frequency Moisture Transducer for Bulk and Fibrous Materials. Devices, Moscow, 2020. No. 3, pp. 33-39. (in Rus.)
9. Usmanova, Kh.A., Turgunbaev, A., Kuziev, B. Research of a Laboratory Installation for Measuring the Humidity Characteristics of Bulk Materials. International Journal of Control and Automation, Vol. 13, No. 4, 2020, pp. 237-244. (in Rus.)
10. Ikramov, G.I., Kalandarov, P.I. Moisture Measurement of Grain and Grain Products Using the Microwave Method. Measurement Technology, No. 9, 2022, pp. 71-76. (in Rus.)
11. Ismatullaev, P.R., Usmanova, Kh.A., Turgunbaev, A. Research of Super-High-Frequency Moisture Measurement Method for Grain Materials. Metrology and Instrument Engineering, Minsk, 2020. No. 2, pp. 8-11. (in Rus.)
12. Usmanova, Kh.A., Turgunbaev, A. Research of the Interaction of Super-High-Frequency Waves with Grain. In: Proceedings of the International Scientific-Practical Conference "CAD and Modeling in Modern Electronics", Bryansk, 2021, pp. 314-317. (in Rus.)
13. Temerbekova, B.M., Usmanova, Kh.A., Turgunbaev, A. Application of the Super-High-Frequency Method for Measuring the Moisture of Bulk Materials in Complex Metallurgical Processes. "Black Metals", No. 4, April 2023, pp. 23-29. (in Rus.)
14. Usmanova, Kh.A., Turgunbaev, A., Abdurakhmanov, O.Kh. Selection of a Moisture Transducer for Bulk Materials. Bulletin of Tashkent State Technical University, 2019, No. 1, pp. 13-20. (in Rus.)
15. Usmanova, Kh.A., Turgunbaev, A. Mathematical Model of Interaction of Ultra-High-Frequency Waves with Wet Grain. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 10, Issue 3, March 2021, pp. 1892-1897. (in Rus.)
16. Usmanova, Kh.A., Turgunbaev, A. Developing a Multi-Purpose Moisture Meter on Ultra-High Frequency. Special Issue of the International Scientific and Technical Journal "Chemical Technology. Control and Management", Uzbekistan, Tashkent, 2018, No. 4-5, pp. 202-206.