The use of lighting techniques for rapid remote determination of moisture content of sunflower seeds growing in the fields

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Abstract. The method is proposed and the ability to perform rapid remote determination of the moisture content of sunflower seeds using millimeter – range microwave radiation is experimentally investigated. A laboratory experimental setup for measuring the reflection coefficient of electromagnetic waves from sunflower inflorescences in the frequency range of 25.86 – 37.5 GHz has been created. Experimental studies of the value of the reflected signal from sunflower inflorescences on both sides of the plant were carried out in order to create a mathematical model that takes into account the difference between the reflected signal from the inflorescence side with sunflower seeds and the reverse side. Experiments were conducted for inflorescences of maturity different degrees.

1. Introduction
In modern technological processes of the agro-industrial complex, methods and devices are required that allow remote monitoring of the moisture of a wide range of crops growing in the fields, in order to enable the farmer to make an optimal decision about the start time and harvesting timing from each specific field. The traditional methods of moisture measuring with a capacitive moisture meters can't cope with this task. This leads, as already indicated in [1], to additional costs for drying grain, which are in the Rostov region, only for sunflower, about 400 – 500 million rubles [1], and throughout Russia these costs are about 1.5 – 2 billion rubles per season. The data refer only to one agricultural crop, and with the other agricultural crops: grain, corn, canola, etc., this figure increases even more. Microwave moisture measurement methods can quickly get information about humidity and some other parameters of agricultural crops. Consideration of several of them are given in the works [2], [3], [4]. However, these studies consider moisture content measurement methods in agricultural products that have already been harvested and prepared for processing. In the papers [5], [6], [7] lighting techniques based on the interaction of the electromagnetic field and the objects under study are used. However, when conducting these studies, the purpose of research was not to measure the moisture content of the agricultural crop particular part, (for example, sunflower seeds). For agriculture, it is the moisture content of the materials that is essential, and not the entire crop as a whole.

2. Main part
This research paper shows that it is possible to use microwave radiation for remote timely of moisture content measurement of agricultural crops growing in the fields. The choice of this range for moisture content control is associated with certain properties of the water dielectric parameters that determine the high sensitivity of the selected range to the water content in agricultural objects.

This method involves three stages: the first stage is the study of changes in the characteristics of the electromagnetic field interacting with an agricultural crop (for example, with a sunflower inflorescence or a corn cob). The measured parameters can be: a change in the amplitude of the electromagnetic wave...
passing through a wet material (E), a change in the phase of this wave (f), the reflection coefficient of the electromagnetic wave from the boundary (environment) \( \text{<< air – material >>} \) (D), the electromagnetic radiation flow density from the wet material (P).

At the second stage, it is necessary to identify the relationship between changes in these parameters when microwave radiation interacts with an agricultural crop (for example, sunflower inflorescences) and the moisture content of the grain material obtained from it (sunflower seeds).

At the third stage, it is necessary to measure a reflected signal from the sunflower inflorescences on the side of the seeds and from the opposite sides to develop a mathematical mode.

3. Method of the experiment

To study the dependence of the reflection coefficient \( |G| \) on the grain material is the most convenient application in the fields. In the sunflower, these are the seeds that are in the inflorescence. Preliminary laboratory tests are necessary for reliable interpretation of data.

The dependence of the value of the microwave signal reflected by the sunflower inflorescence on the moisture of sunflower seeds located in this inflorescence was defined during laboratory studies. The measurements were performed at frequency \( F = 30 \text{ GHz} \). The power of the reflected inflorescence signal in the microwave spectrum noticeably depends on the distance from the inflorescence, from the angles of incidence and the reflection of a signal from moisture content of sunflower seeds. \[2\], \[8\]. The block diagram of the experimental installation for measuring the reflection coefficient \( G \), in the frequency range 25.86 - 37.5 GHz, is shown in figure 1.

![Block diagram of the experimental installation](image)

**Figure 1.** Block diagram of the experimental installation. 1 - Indicator of VSWR and attenuation of \( Y2\Pi-67 \); 2 - Swinging frequency oscillator (SFO); 3 - Waveguide junction; 4 - Directional radiated signal detector; 5 - Directional reflected signal detector; 6 - Horn-type receiving and transmitting pyramid antenna

The moisture content of seeds in the inflorescence was determined after measuring the reflection of the microwave signal using the “Fauna-M ” capacitive moisture meter. The error in determining the volumetric moisture content (D) when using this equipment was no more than 0.5 %.

Inflorescences with seed moisture content from 7% to 16% were used for measurements, since it is in this range that the humidity of conditioned seeds is located. Humidity of 7% is the base for taking sunflower seeds in most elevators.

Since the power of the reflected microwave signal depends on the distance to the inflorescence and on the angle of incidence and reflection from it, in order to exclude the interaction of these effects, the
inflorescences were placed strictly perpendicular to the receiving and transmitting horn, and the measurement result was represented as the ratio of the reflection coefficient $|G|$ at a given moisture content to the reflection coefficient $|G_0|$ at a base moistness 7%. Both these coefficients are identical depending on the distance between the receiving horn and the sunflower inflorescence. It is obvious that these coefficients depend equally on the angle of incidence of the microwave signal on the sunflower inflorescence. During the experiment, more than 100 sunflower inflorescences were studied; the average values obtained are shown in the figure 2.

Figure 2. Experimental dependence of the modulo-normalized coefficient of reflection of microwave radiation (measured in decibels (DB)) on changes in the volume humidity (D) of sunflower seeds in the inflorescence

When measuring the moisture content of sunflower seeds directly in the fields, more than one inflorescence will fall into the directional diagram (DN) of the transceiver, while some inflorescences will be turned to the receiver with the side, where the seeds are located, and some of them will be turned with the other side. In this case, to compare the power of the reflected microwave signal and the humidity of sunflower seeds, you need to create a mathematical model that takes into account the difference between the signal reflected from the side with sunflower seeds and the signal reflected from the reverse side at a certain humidity of sunflower seeds.

For further mathematical model development, measurements were made from the side of inflorescences with seeds and from the reverse sides of sunflower. A field in the Rostov region, located in the Myasnikovsky district, was selected for the study. Measurements were made with sunflowers of different degrees of maturity. No precipitation has fallen in this area since the measurements were made. The data obtained are shown in figure 3.

Figure 3. Dependence of the microwave signal power (in DB) on the sunflower inflorescence from the seed side and from the reverse side depending on the time (by day)
The abscissas axis shows the time during which the study was carried out. The ordinate axis shows the power of reflected microwave radiation.

The analysis of the obtained data shows that the reflection of the microwave signal from an immature sunflower is greater than from a mature one. Sunflower seeds reflection (dashed line) is less than the reflection from the reverse side, more than 0.5 DB. Immature sunflower moisture measured by a capacitance moisture meter was more than 13% until September 9. Since September 9, the capacitance moisture meter has demonstrated moisture content of about 9-10%. On September 14, the moisture content was less than 8%, and the sunflower could be considered ripe.

The difference between the signal from the sunflower signal side and the reverse side decreased as the sunflower matured and did not exceed 0.1 DB (when the sunflower was fully ripe) by September 14. The ordinate axis shows the power of reflected microwave radiation.

**Conclusions**

Thus, based on the data obtained, the following conclusions can be done:

The obtained data show that when the moisture content of sunflower seeds changes from 7% to 16%, the power of the reflected microwave signal decreases by about 20%. Therefore, it is possible to detect the moisture content of sunflower seeds by changing the value of the signal reflected from the sunflower inflorescence.

The reducing power of the microwave signal can be explained by the higher absorption coefficient of the microwave signal with increasing moisture content.

As a result, the curve of the microwave reflection coefficient normalized in modulus from the change in the volumetric moisture content of sunflower seeds in the inflorescence (Fig. 2.) can be used in the form of a calibration graph, which makes it possible to determine by the change in the reflected value of the microwave signal relative to the reflection from the inflorescence with a base moisture content of 7% bulk moisture content of sunflower seeds.

According to the results of the second experiment, it was revealed that:

The reflected signals from the fruit of sunflower seeds and from the reverse side of the inflorescence for mature sunflower are almost identical. This makes it significantly easier to build a mathematical model that should be used in the proposed method for determining the sunflower seeds moisture content for a fully grown sunflower.

The difference in the reflected signal from the two sides of the inflorescence exceeds 0.5 DB for unripe sunflower. Probably, in the future, this fact can be used for diagnostics and maturation time of sunflower growing in the fields.

At the moment, the study is not complete yet, since to build a correct mathematical model, the value of the reflected microwave signal at the base moisture content at all possible angles and distances must be measured and entered into the processor, after which this calibration curve is allowed to be applied at any distance between the receiving horn and the sunflower inflorescence, as well as at all angles of incidence of microwave radiation on the inflorescence.

**References**

[1] Kunakov V and Litvishchenko 2010 Method of remote Express research of moisture of agricultural crops and materials growing in the fields using microwave radiation. *Materials of the international scientific and practical conference on March 4 - 5, Rostov-on-Don within the 13th international agro-industrial exhibition*

[2] Benzar V 1974 *Technique of microwave moisture measurement* Vesshaya shkola, Minsk

[3] Lisovsky V 2005 *Theory and practice of ultra-high-frequency moisture control of agricultural materials* BSATU, Minsk
[4] Lisovsky V 2006 Modern methods of Express measurement of humidity of agricultural materials. BSATU, Minsk
[5] Golovachev S, Chukhlantsev A and Shutko 1987 A Experimental study of microwave radiation of crops from a mobile unit Abstracts of the XV all-Union conference on radio wave propagation, Moscow, Nauka, pp. 408-409
[6] M Aniszewska M, Stowinski K. 16 June 2016 European Journal of Forest Research Effects of microwave irradiation by means of a horn antenna in the process of seed extraction on Scots pine (Pinus sylvestris L.) cone moisture content and seed germination energy and capacity volume 135 p 633-642
[7] Kiczorowska B, Samolinska W. 2019 Journal of Food Science and Technology Comparative analysis of selected bioactive components (fatty, acids, tocopherols, xanthophyll, lycopene, phenols,) and basic nutrients in raw and thermally processed camelina, sunflower, and flax seeds.
[8] Grankov A, Milynin A, Chukhlantsev A and Shelobanova N 2004 Spectral features of radiothermal radiation of a forest canopy Proceedings of the LVIX scientific session of NTORES after A.S. Popov, 146 – 148
[9] Armand N, Grankov A. and Milynin A. 2001 Possibilities and prospects of using satellite microwave - radiometric devices of the decimeter range for remote sensing of the Earth. On Sat. Remote sensing of the earth's covers and the atmosphere by aerospace means. All-Russian Scientific conference, Murom.
[10] Pipinis E, Stampoulidis A, Milios E, Kitikidou K, Akritidou S, Theodoridou S, Radoglou K. 21 November 2018, Journal of forestry research Effects of seed moisture content, stratification and sowing date on the germination of Corylus avellana seeds volume 31, pages743–749(2020)
[11] Gawrysiak-Witulska M, Rudzinska M, Wawrzyniak J, Siger A, 2012 Journal of the American Oil Chemists’ Society The Effect of Temperature and Moisture Content of Stored Rapeseed on the Phytosterol Degradation Rate volume 89 pages1673–1679
[12] Gambhir P, Agarwala A. 1985 Jornal of the American Oil Chemist’s Society Simultaneous determination of moisture and oil content in oilseeds by pulsed nuclear magnetic resonance.
[13] Litvishchenko V and Kunakov V 2011 Method for grain determining of grain crops. Patent for invention No. 2438117.-publ. 12/27/2011 bul. No. 36