Design and implementation of a device for a cloudiness measurement

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Abstract – **In the paper are investigated the algorithms for measurement of cloudiness. First is the HYPERION algorithm, second is presented the process of development of a real one device, based on Thermopile sensors. The requirements for such an apparatus for hardware and software development are fulfilled.**

Keywords – **HYPERION algorithm, thermopile sensor, cloudiness measurement, cloud cover.**

I. INTRODUCTION

Analysis of weather conditions is an important part of our daily life. In the busy air traffic, clouds affect the visibility, and hence the security of flights and satellite researches. For these reasons, a development of algorithms and devices to measure the density of the clouds is necessary.

One of the most important features in their development are compact of the device, low cost, ease of use.[1] For this reason are conducted both scientific and practical research in this area. One of the leading organizations working in this direction is the European Organization for the Exploitation of Meteorological Satellites.

Cloud monitoring has been developed for use with cosmic ray air shower fluorescence detectors, the High Resolution Fly's Eye and the Pierre Auger Observatory. This is based on an infrared thermopile device which, unlike previous such monitors, requires no moving chopper and is suitable for unattended operation over long periods of time.[2]

There are various devices and ways to measure cloud cover. One of the easiest ways is the photo. Unfortunately, the data obtained from them is difficult to be processed. In this method, the human factor is crucial and there still remain difficulties in the process of evaluating the data to be automated. The equipment required to perform the algorithms for image processing are expensive, but also dependent on the environmental conditions.

The analysis of cloud characteristics is very important because it gives the method to differ the cloud form the rest of the environment. Tracking them is the basis to make a correct assessment of their parameters (such as density, height, etc.). The main characteristic is the reflection of light. If the reflection of the light rays and the characteristics of reflection are tracked, then any change in the background indicates the presence and type of cloud cover. [3]

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II. ALGORITHM FOR MEASUREMENT OF CLOUDYNESS IMPLEMENTED ON HYPERION

A. The Hyperion

A cloud cover detection algorithm was developed for application to EO-1 Hyperion hyper spectral data. The algorithm uses only bands in the reflected solar spectral regions to discriminate clouds from surface features and was designed to be used on-board the EO-1 satellite as part of the EO-1 Extended Mission Phase of the EO-1 Science Program. The cloud cover algorithm uses only 6 bands to discriminate clouds from other bright surface features such as snow, ice, and desert sand. The code was developed using 20 Hyperion scenes with varying cloud amount, cloud type, underlying surface characteristics and seasonal conditions. Results from the application of the algorithm to these test scenes is given with a discussion on the accuracy of the procedure used in the cloud cover discrimination. Compared to subjective estimates of the scene cloud cover, the algorithm was typically within a few percent of the estimated total cloud cover.[4][5]

The Hyperion devise is a satellite to the Earth with embedded tools for monitoring. On the meeting of EO-1 SVT on Nov 21, 2002 was introduced algorithm for image capture, according to which clouds are excepted from the rest of the earth objects. [6][7] The reflected light from the cloud is used. The image is processed pixel by pixel, and is defined which pixel is covered and which is not. That is the method for assessment of cloud cover as a percentage of the taken image. On the basis of the algorithm is the image capturing in 6 frequency channels:

0.56 μm - used to calculate the index of snowing,

0.66 μm - main channel for testing the effect of clouds reflection,

0.86 μm – it is used with 0.66 μm for testing NDVI,

1.25 μm – differentiation between desert and sands,

1.38 μm – channel testing of high clouds position,

1.65 μm - used to calculate the index of snowing.

For each frequency band *i* using the following formula to convert the calibrated data in Hyperion L_i in reflections ρ_i:

$$\rho_i = [\frac{\pi}{\mu_0 S_{0,i} / d^2_{earth-sun}}]L_i \tag{1}$$

The result is a value for each reflection spectrum of each pixel of the image. Based on the values of the reflection ρ_i is developed algorithm, which determines whether a pixel is a reflection of clouds (low, medium high or high), whether or desert sand, snow, ice, water or plant. [7]

B. Algorithm implemented on the device developed and tested during the experiments

In the present paper is chosen for cloud cover measurement the effect of a thermal radiation.

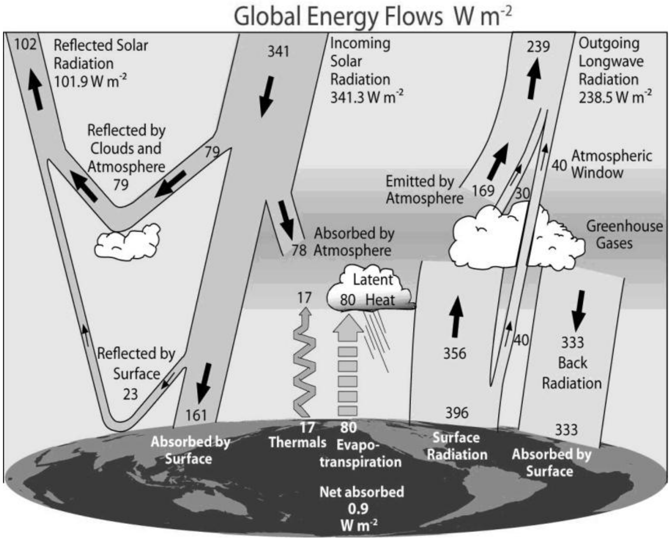

Fig. 1. Global energy flow on earth. Return of greenhouse gases and clouds of energy.[8]

The sun emits heat that reaches the ground. During the process of reaching the Earth the energy is accumulated, depicted on the right part of Fig.1. The Earth itself begins to radiate heat, which is directed towards the sky - left side of Fig.1 On crisp, clear sky, the earth radiated energy is not absorbed and is send back to earth. The more the emitted from the sky energy is, the more dense of the cloud is. It is measured by the difference in radiated from the ground and returned from the objects in the sky heat.

The quantitative assessment of these effects is performed by thermopile sensor.

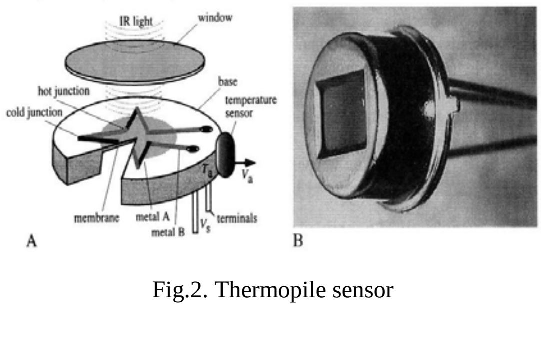

Fig.2. Thermopile sensor

The thermopile sensor is a set of thermocouples connected in series, rarely parallel. The sensor measures the thermal radiation of the objects. When thermal radiation reaches the sensor one of each pair of thermocouples is heated. This couple is called active. Another thermocouple is thermally isolated from the environment.

Between heated and protected thermocouple is created an electric potential which is proportional to the difference in temperatures between the two transitions.

Since the paired thermocouples are connected in series the generated voltages are collected, and as a resultant tension between the outputs of the two sensors.[8]

Extremely favorably during the measurements is the falling of drops of water on the sensitive surface. In this case the water acts as a lens and focuses the sensor at a point in the sky that can be not correct to the overall cloud cover. To avoid such errors in the measurements must be foreseen a system for removal of droplets and drying of the sensors.

C. Requirements for the device

The device for measuring cloudiness is a part of the weather system that also measures temperature, humidity, barometric pressure, rainfall and location of lights and their power. The main function of the device is to measure proven the amount of clouds in a specified perimeter. Assessment of the cloud is made according to a scale consisting of 8 units called octaves. This is an international scale standard METAR [1]. The lowest level of clouds is in the first octave, and the highest in the octave with number 8. The information from the device is collected in a centralized system that processes the results of all instruments and transmits the information to the upper levels of the system for visualization. The protocol for conducting communication between the device and the system is RS485. The message to be generated by the clod measure device has a specific format specified by the system which will received it and will have to process it.

III. THE DEVICE

The device structure is also presented here. The main building blocks are depicted on Fig.2 .

1. *Interfaces*

Because the device is mounted outdoors, the block interfaces, which is RS485 interface is implemented in a weather-proof box. This ensures low contact resistance and high reliability of connection. The communication lines are secured and strengthened against wind and mechanical effects.

2. I/O transmitters block

It consists of interface circuits that convert the signals. The CMOS levels, with which the microcontroller works are not suitable for establishing communication links over long distances. Therefore, are used interface circuits, level transformers that ensure reliable data transmission. A communication channel is build with defined bandwidth and noise protection.

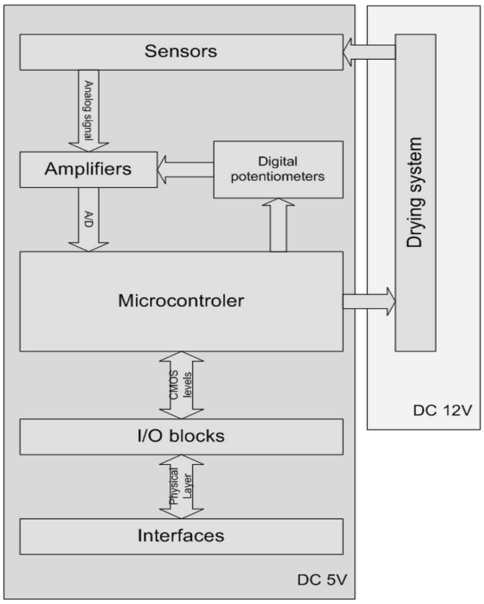

Fig.3. Block Scheme

3. *Microcontroller*

Microcontroller is the main component of the device. It is responsible for the connection between all the blocks of the device, and communication with the centralized system. The microcontroller measures the signals from the sensors, uses built-in A/DC to digitize the data. Then process and prepares them for transmission in a convenient, easy to understand format. Instrument calibration is also performed by the microcontroller in two stages:

1. The sensors are established to generate one and the same signal level. This means that under the same conditions each of the four sensors will show equal values. This represents unification of "zero" on the sensors and ensure that readings are equally relevant for the purposes of measurement.
2. The reporting of the results of the cloud measurement is presented in 8 octaves. To define in which octave is the current value of the cloudiness are defined ranges. The correct values (thresholds) are set, which are the base to pass from one octave to another according to initial levels of the sensors and model device.

The “zero” levels are adjusted on amplifiers with digital potentiometers. The calibrated thresholds are stored in an array of values embedded in the microcontroller EEPROM. In the EEPROM is stored data and device as ID, speed of data transmission and more.

Communication with the centralized system is done using a built-in microcontroller USART interface. It works with 8 bit register; it is possible to configure the start bit, parity check and one or two stop bits. The speed is up to 76,800 boudps.

4. *Amplifiers*

Since the signal level which is provided after the measurement is low, the sensors will produce very similar values for different clouds. This is a prerequisite for a wrong switching between the upper and the lower range. For these reasons, the signal is amplified. Thus, achieving levels similar to those the microcontroller works, used is the full range of the A/DC, which is 10 bits. In this way the thresholds for switching different octaves, are moved away from each other with which reduces the probability of error acquiring in measurement.

For the practical purposes is realized electrical scheme for the digital part of the device.

The electrical circuit scheme is based on the microcontroller ATMega8L. [2] For the realization of interface RS-485 is chosen the DS75176. The element is interface scheme which from the side of the microcontroller operates with CMOS levels, and on the side of the channel to connect a differential amplifier. The amplifier eliminates the noise in the communication channel and amplifies only the desired signal. This feature gives the possibility data to be transmitted on long distances without loss in the payload. The DS75176 is suitable for the purposes of the studied realization, because the source power is 5V, which is the same as the voltage of the processor. The connections scheme and the terminating resistor values are taken from the specification of the integrated circuit.

The signal flow in transmission of the information is as follows: the microcontroller sends bits coded with CMOS levels, which are serially transmitted from the seventh otput of the microcontroller, which is a part of the USART protocol, bits are taken from an agreed scheme on the fourth output D, which is an input working with CMOS. If DE and RE are with a high level then the data is transmitted. If they are with lower level will have to wait for an acceptance from the receiver. The outputs RE and DE are conducted by the microcontroller. There is ability to work in full-duplex or half duplex mode. This option is selected during installation of the device from jumper. In half-duplex mode, DS75176 is in receiving mode on both sides of the line. To start, transmission is checked that the transmission line is free, if so, can begin transmission. In full duplex mode one the scheme is in receiving mode and the other is in transmission mode. The schemes on the other site of the channel are in opposite mode. In receiving mode, the receiving buffer will decode the differential signal from the channel in CMOS levels, which are transmitted to the RXD output of the microcontroller. The bits are stored in 8-bits long register. In the formation of a word a flag is raised in the register of the microcontroller that there is information to be processed.

The power of the digital and the analog parts of the scheme is divided. The reason is the high sensitivity of operational amplifiers.

5. *Software*

Software for implementation in the device is also developed.

The algorithm for management of the cloud measure device can be conditionally divided into two parts:

1. Command interpreter – its purpose is to process information that is entered by the user via RS-485. This information is a string of symbols that have meaning of a command. After the acceptance of the string, it is processed and the command is recognized, it is executed and again goes into standby mode for reception of a new command. The cloud measurer remains in this mode until a command will be entered, get into a break or the power is not switched off.
2. Process of measurement – implemented in hardware interruption by time. The interruption may occur at any time from the work of the command interpreter. The current values of the registers are saved in a stack of interruptions. Runs the code in the breaking. Then from the stack of interruptions are recovered the old values of the registers and the system continues the execution of the command interpreter.

The design of the device includes not only implementation of the defined algorithm, but also a hardware realization.

6. *Hardware design*

The instrument measures the local cloud cover by Thermopile sensors, which records the thermal radiation The device is working on a comparative basis.

1. The device is a part of the weather system. Successfully communicate with the central module of the system. The format of the data is correct, consistent with the system and it recognizes successfully results.
2. The device is compact. The integrated shell gives possibility of an easy change of the parameters of the device and fast calibration.
3. With the embedded mechanisms for self diagnosis the device reports dropped power of the amplifiers or system for drying, decisions for automatic power on of the system.
4. With the use of calibration arrays of the measurement results are accurate and are not influenced by changes in the environment.
5. The design of the device includes the most modern components. The microcontroller has a built-in mechanisms to monitor power and low power consumption. The appliance has been tested in a specialized laboratory for electromagnetic compatibility and has passed the tests successfully.

IV. Conclusion

After the calibration of operational amplifiers and proper setting of arrays according to which is determinate the octave of the cloud, measurements are accurate and report the actual cloud cover. The device has been tested several months. During the test period is checked the behavior of the device in climate changes from winter to spring. The changes of atmospheric environmental conditions were successfully ignored by the measurement and it remains within the seasons change. To achieve this, several arrays were used to determine the octave of the cloud. The unit automatically determines which array to work with on the basis of the reference sensor. The drying system was also tested in real conditions. In rainy weather the system works successfully, and the events for the selection of automatic activation of the system are appropriate and work.

After the tests the device was approved for use.

The command interpreter provides excellent opportunities to configure all device parameters. This makes it more flexible and convenient for use in different conditions. Using Remote Desktop, interpreter allows remote configuration, which is especially useful for system maintenance. Thus saving much time and effort to remove the smaller problems.

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