MATHEMATICAL MODELING OF altimeter

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The aim of the survey is to simulate photon altimeter designed for a soft landing on the lunar surface. Simulation of the process of scattering of gamma rays from the lunar surface with a typical composition of the lunar soil was implemented.

*Keywords:* photon altimeter, lunar soil, gamma rays.

**Introduction**. Photon altimeter designed to measure the distance between the lander and the underlying surface. Altimeter should measure the current height of lander on the lunar surface in the range from 0.3 m to 10 m at a rate of descent of 6.5 m/s to 11 m/s providing that random component of the relative error does not exceed3%. For this purpose, a photonic altimeter working on the reflected gamma - radiation is developing. Conditions of landing on the moon surface seriously differ from conditions on Earth due to the lack of the lunar atmosphere, the high background radiation and soil composition of the lunar surface.

Amount of reflected gamma rays depends on the type of the underlying surface of the Moon [1]. Lunar surface consists of loose material called regolith, which consists of fragments of bedrock and secondary particles. Material formed as a result of shock-explosive material processing so-called breccia and glass particles in meteoritic bombardment of the Moon. The average depth of the regolith that covers the entire surface of the Moon without exception , ranges from 4-5 m in the lunar seas up to 10-15 m on the continents . Chemical composition reflects that of the regolith overlying rocks below , but it also contains other substances and minerals. The main minerals of lunar rocks : plagioclase (solid solution of albite and anorthite NaAlSi3O8 CaAl2Si2O8), orthopyroxene (Mg, Fe) SiO3, clinopyroxene (Ca, Mg, Fe) SiO3, olivine (Mg, Fe) 2SiO4, ilmenite (FeTiO3) and spinel-group minerals (FeCr2O4 - Fe2TiO4 - FeAl2O4)

Lunar sea are volcanic plains that fill cavities in the topography of the continents. The predominant type of lunar sea rocks are marine basalts. Lunar sea more suitable for landing space craft.

**Algorithm for calculating intensities of flows.**

Altimeter uses the effect of gamma-ray scattering or the Compton effect. The differential cross section for Compton scattering by one electron per unit solid angle is given by the Klein-Nishina-Tamm:



where - the scattering angle,-the classical electron radius, ,-constant,-wavelength effect,-electron mass,-the speed of light,  keV- the energy of the primary radiation, - the ratio of photon energy to the electron rest energy at,

To a mixture of substances on the lunar surface can calculate the effective number of underlying soil surface by the formula:.



The electron density of the underlying surfacewhereis Avogadro's number, - atomic mass,-atomic number of the element of lunar soil. Compton cross section. Intensity of the scattered photon radiationdepending on primary radiation , the scattering angle at a distancefrom the scattering electron is given by formula:

Calculations showed that the intensity of the scattered radiation decreases with increasing scattering angle. In the range of interest from 90degreesto 180degrees of scattering angle sat a photon energy of 660keVintensity of gamma-ray does not change dramatically. Therefore, it is advisable to work in this range.

The energy of the scattered photons depends on the angle of scattering in accordance with the relationship:



Energy gamma rays decreases within creasing scattering angle.

If the value of the scattering angle of the scattered energy is reduced as compared with the energy of the primary radiation and close to 200keV.The energy of the scattered photons at angles less than the operating range depends on the energy source. The geometry of location of one gamma radiation source and four detectors receiving gamma radiation scattered on the surface, is shown in Figure 1.

D44

S

D1

D2

D3



Fig.1. The location of the source and four detectors

Photon radiation source ( FI) arranged in the center, four detectors ( D1-D4) disposed on the edges equidistant from the source. Lander may be tilted relative to the underlying surface , wherein the angle of slope of the axis on which the two detectors are located. The current value of the height of the landing apparatus, the angle of incidence of the direct beam of gamma rays - the angle between the projection of the axis of the detector location D1 and radius passing through the point of incidence - . Scattering angle of gamma-ray that detector registers D1.

The detector receives the gamma ray scattered from the lunar surface in accordance with the angle of collimation of the radiation source. Calculate the integral of intensity ratio of primary and scattered fluxes of gamma rays over the volume of interaction with the ground. Integral depending on the angle of incident flux(), the depth of penetration of gamma rays in soil () on which there is a scattering, height . Algorithm for calculating the ratio of the intensities of flows is as follows:

- integration in terms of substance scatters;











Angle of incidence of the direct photon flux;



Distance from the scattering element to the detector;



The cosine of an additional angle scattering angle;



Elementary scattering volume;





Photon flux, taking into account the absorption;





Amount of electrons in elementary volume  is given by following equation:



where  is a matter density,  mole-1 is the Avogadro constant numerically equal to amount of elements (electrons, molecules, atoms) in one mole of material, mole is amount of material comprising number  of atoms,  is a mass of one mole (molecular weight of mole).

Mass absorption factor of gamma-ray quantum with energy 660 keV by silicium equal  cm/g2. Mass absorption factor of scattering gamma-ray quantum with energy 200 keV by silicium equal  cm/g2.

Scattered gamma quantum reaching detector is given by following equation:



where  - matter density, - distance between gamma-ray source and scattering element.

**Numerical experiment..**

The proposed model is implemented as a simulation program running in the Matlab package.. Height of descent module dependences of average intensity of scattered gamma quantum reaching detector D1 are presented in figure 1.

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γ=0

γ=0

γ=0.098

γ=0.393

γ=0.295

γ=0.196

γ=0

Figure 1. The height of descent module dependences of average intensity of scattered gamma quantum

Signal received by detector is more powerful when height of descent module is small. The height and slope angle can be measured mach more accurately when height is small. This fact is an advantage of photon altimeter. It is more difficult to measure height and slope angle on big height of descent module.

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Figure 2. Dependences of slope angle measured on difference height

Results of modeling of altimeter shows that standard deviation of error of slope angle in respect to small height of descent module is not grater then 0.01 radian. In respect to big height of descent module error of slope angle is about 0.01 radian.

**Summary.**

The model users following initial values: required activity of photon sources, topology of photon sources and detectors, initial value of height.

The model allows to determine the basic characteristics of the altimeter: result of a measurement altitude, result of an angle of slope, uncertainty of result of a measurement altitude and uncertainty of result of a measurement angle of slope.

**References**

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