STUDY OF POTENTIAL USE OF GROUND-BASED RADIOELECTRONIC EQUIPMENT RADIATION REFLECTED FROM ORBITAL SPACE OBJECTS

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Abstract- The article considers the findings of direct and reflected radiation of ground-based radioelectronic equipment from low Earth-orbiting satellites. Calculation of transmitting device capacity is presented. The author conducted a study on the use of ground-based radioelectronic equipment radiation reflected from low Earth-orbiting satellites.

Keywords- Space Objects, Radio Communication, Reflected Radiation

I. INTRODUCTION

The major components of this radio communication system are transmitter, receiver, antenna and terminal device (Figure 1). Radio transmitter generates high frequency oscillations with amplitude, frequency and phase modulation. These oscillations are transmitted to antenna which generates a direct signal. A sequence of short radio pulses equally spaced in time is commonly applied as a direct signal.

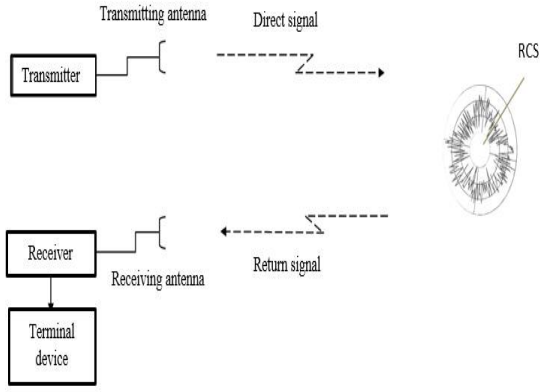


Figure 1 – System architecture

As an electromagnetic wave hits a group of objects, it generates electromagnetic field oscillations and the object creates its electromagnetic field as a usual antenna. This field is a scattered or reflected electromagnetic wave which has the function of information carrier. The objects of this system are artificial low Earth-orbiting space objects which can scatter and reflect electromagnetic radiation. The objects contribute to inhomogeneity of the open space. As ε_a and μ_a parameters of their surface differ according to ε_o and μ_o environments, consistency of radio wave propagation velocity vector is disrupted. As a result the object converts the radio signal: some part of the energy is reflected back, another part is absorbed by the object, and if the object is radar-transparent, the energy is refracted, changing the direction of radio wave propagation. The case when the object is the source of scattered radiation is interesting for the analyzed system.

Radio receiver is used for separation of the desired radio frequency signal from all the other signals (primary processing of the signal). The required strength of the signal reflected from the objects can be achieved by increasing the power of radio transmitter; increasing the size and effectiveness of transmitting and receiving antennas; bandwidth reduction, pulse width increase and information transmission rate reduction. Terminal device is used for conversion of the signal into the form suitable for the customer.

Power of the reflected radiation depends on radar cross-section (RCS), S_{efo}, which in its turn depends on the main reflecting properties of the objects such as object size (the area of object projection onto the plane perpendicular to the radio wave propagation direction), configuration, surface material, radiowave length, its polarization and propagation direction. The power of the return signal in the receiving antenna is given by the following equation:

$$P_s = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R_1^2 R_2^2 L}, \qquad (1)$$

where, P_t – transmitter power, W
G_t – gain of the transmitter, dB
G_r – gain of the receiver, dB. In the case of monostatic system (radar), transmitter and receiver gains are equal.
λ – wavelength, m
σ – radar cross-section, m^2
L – system loss, dB
R_1 – distance from the transmitter to the objects,
R_2 – distance from the objects to the receiver. In the case of monostatic system, the distances are equal.

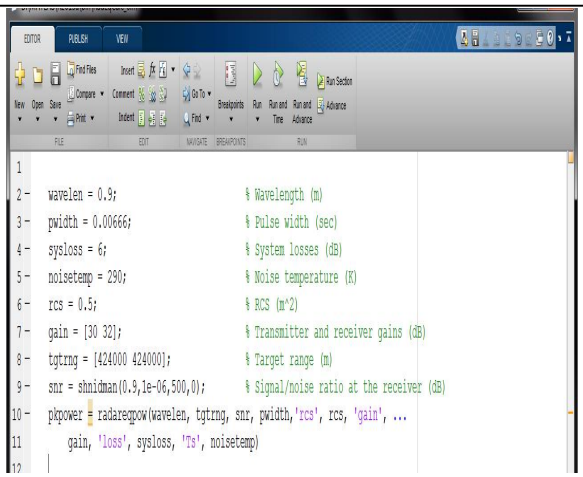
This equation determines correlation between the power of return signal P_s and transmission power P_t. Formula 1 shows that the power of return signal declines very fast – in inverse proportion to the 4th power of the range – with increasing distance to the objects. Therefore, the power of return signal is relatively small and the signal itself is incidental.

Small power of the signal is explained by long distance to low Earth-orbiting objects and signal absorption during its propagation. Random character of the signal is the result of return signal fluctuations due to movement of certain objects of the group under radio wave reflection, multipath wave propagation, chaotic modulation of signal amplitude at propagation and other factors. As a result return signal in the receiver is similar to noise and interference according to appearance, intensity and behavior. Thus first and foremost function of the system is detection of the desired radio frequency signal, i.e., identifying presence of desired signal in the input mixture of desired signal and interference which is called input realization. This statistical problem is solved by a special device called detector which uses optimal detection algorithm. The quality of detection process is characterized by probability of correct detection when input signal is detected and probability of false alarm when interference is taken for desired signal but there is no signal.

Matlab environment has Radar Equation Calculator application which helps to detect the required power of the transmitter signal according to formula (1) (Figure 2). The following data must be entered: wavelength, pulse width, system loss (dB), noise temperature and radar cross-section, transmitting and receiving antennas gain, signal/noise ratio at the receiving antenna (probability of detection, probability of false alarm, signal number) and target range. The calculations in Radar Equation Calculator application for the analyzed radio communication system used parameters given in Table 1.

Table 1 – System Parameters

Parameter	Value
Wavelength λ, m	0.9
Pulse width, msec	6.66
System loss L, dB	6
Noise temperature, K	290
Radar cross-section σ, m^2	0.5
Transmitter gain G_t, dB	30
Receiver gain G_r, dB	32
Transmitter to objects distance R_1, km	424
Receiver to objects distance R_2, km	424
Signal/noise ratio at the receiver:	
Probability of detection	0.9
Probability of false alarm	10^{-6}
Signal number	500
Peak transmitter power	**69.24**



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wavelen = 0.9;                  % Wavelength (m)
pwidth = 0.00666;               % Pulse width (sec)
sysloss = 6;                    % System losses (dB)
noisetemp = 290;                % Noise temperature (K)
rcs = 0.5;                      % RCS (m^2)
gain = [30 32];                 % Transmitter and receiver gains (dB)
tgtrng = [424000 424000];       % Target range (m)
snr = shnidman(0.9,1e-06,500,0); % Signal/noise ratio at the receiver (dB)
pkpower = radareqpow(wavelen, tgtrng, snr, pwidth,'rcs', rcs, 'gain', ...
    gain, 'loss', sysloss, 'Ts', noisetemp)
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Figure 2 – M-file of Radar Equation Calculator Application

In the given example to detect the desired signal in the terminal device the peak transmitter power must be 69.24 W. One of the ways to decrease transmitter power is to increase the number of pulse signals. Calculation results shown on Figure 3 are received by increase of signal number from 500 to 5000 in increments of 500 signals. When 5000 signals are accumulated in the receiver with peak power of 20 W there is a possibility to receive a desired signal reflected back from a group of low Earth-orbiting space objects at a height of 424 km from the Earth surface.

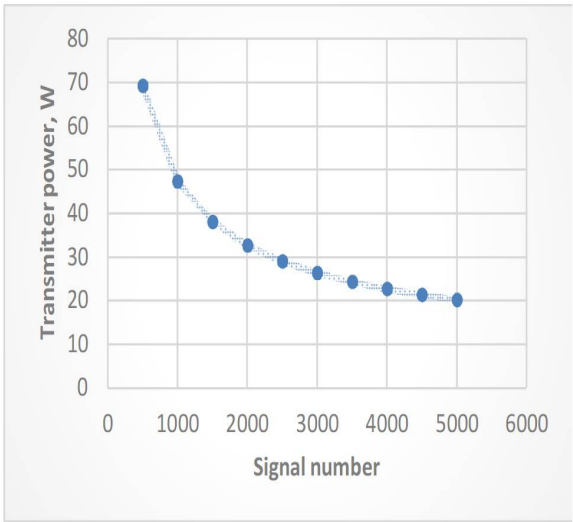

Figure 3 – Transmitter power and signal number dependence diagram

Visualization of real and imaginary components, magnitude and phase diagrams, signal autocorrelation, spectral analysis of signals, etc., have become possible due to Matlab Radar Waveform Analyzer application. You can also make calculations of minimum and maximum range, range resolution, etc. To do this you must indicate the following parameters: sampling rate, signal number, pulse width, system losses, bandwidth, etc. Figure 4 shows analyzer of the real and imaginary components of the signal.

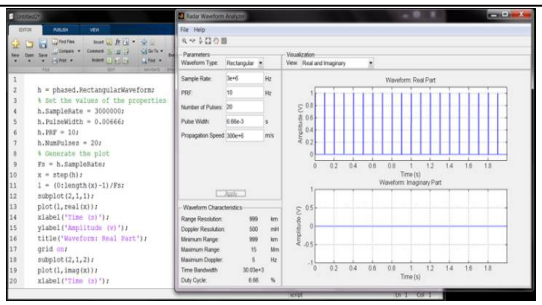

Figure 4 – M-file and analyzer of the real and imaginary components of the signal

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