Frequency Characteristics of Meteor-Burst Channel for TV Signal Reception

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Abstract: ***The possibility of the experimental research of the Meteor-burst channel (MBC) frequency characteristics is presented in this work. The simulation of the transmission of the TV signal through the MBC is completed and its energy's characteristics are studied. The features of the receiving equipment based on energy characteristics of the MBC are developed and the receiver's sensitivity corresponds to the meteor burst electron density is discussed as well in this paper.***

Keywords: Meteor-burst channel (MBC), frequency characteristics, energy characteristics, electron density, about four key words separated by commas.

1. Introduction

Meteor burst wave propagation has been known since early of 1930s. It is based on the VHF band wave reflection from the meteor ionized trails.

The transmission of information using meteor burst communication (MBC) reaches a distance of 2000km with an average transmission power of 10W. The main characteristics of the meteor-burst channel are described by Kascheev [1]. The characteristics of the meteor burst channel researches are performed by meteoric radiolocation stations. Some problems associated with such type of communication can be solved by applying the noise-like signals.

In this paper, the use of noise-like signal in meteoric burst location and communication offers many advantages that will clearly appear through the mathematical modeling.

Since 1970's, automatic meteor-burst radiolocation station was especially built for radio wave reflection from meteor trails. Results of these researches are used for the meteor-burst communication systems development. Ionospheric backscatter sounding is the one of the problems that occurs when meteor burst radiolocation system is used. Interferences level is huge in period of high solar activity in the summer leads to research information loss.

It is necessary to provide effective protection against interferences that is based on the ionospheric backscatter sounding. Using the code division of the signals is a good solution for this problem which will be described in this paper.

MBC upgrade by using noise-like signals can increase the average transmission speed. Also it can increase information security because an enemy agent must have pseudo-noise code for information interception.

The complications of using noise-like signals in the MBC will be described in this paper. The possibility of an experimental research for the response characteristics will also be described. We believe that this paper can be useful for development of MBC system that uses noise-like signals.

It is required to choose a wide band signal for amplitude-frequency investigation response. It is worthwhile to make pre-modeling in order to produce the requirements for experiment's equipment before performing the experiment. Also it needs to check random characteristics of the MBC, as well as the electron density of the meteor trail.

2. Noise-like signals use in a meteor burst locations

As well known, meteor bursts are arisen on (80→105) km altitudes [2, 3]. Line-of-sight distance to the most meteors is equal to (150→300) km if angle of altitude of the antennas radiation pattern is equal to 30^{o} [4]. For other distances, meteor reflection quantity is less which explains why they are not significant in calculations.

Backscatter sounding is based on the VHF wave reflections from the charged ionosphere. Ionization level is based on the critical angle and distance to reflection region. The reflection region length and signal level can be varied. BSS observed distance can be equal to (900 → 2500) km; reflection length is few hundreds of kilometers. BSS signal intensity can be similar to the intensity of desired MBC signal. A BSS distortion is illustrated in Figure 1.

Backscatter sounding interference would not be a problem for meteoric observation if the period of the sounding signal is more than 20 *ms*. When the signal is reflected from meteoric, the burst amplitude-time characteristic arises as can be shown in Figure 1. Average meteor trail lifetime is 300 milliseconds. The time changing of the amplitude-time characteristic is few milliseconds. If the sounding signal with 20 milliseconds period is applied, it will not be possible to take an accurate idea about the amplitude-time characteristic.

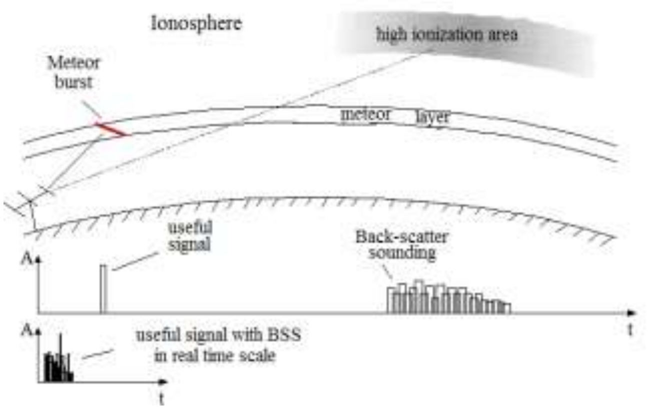


Figure 1: The nature of backscatter sounding

Protection from such kind of interferences is the signals' code division. It is possible to implement such mechanism by using the complex spread-spectrum signal (e.g. noise-like signal). As mentioned earlier, 10 different signals are needed for the system to operate properly. Noise-like signal receiving is performed by correlation processing. It is required to choose 10 signals with a low level of cross-correlation. A similar mechanism is used in global positioning system (GPS), it uses 1023-position signal [5, 6]. On the other hand the use of a signal with a large base could complicate its reception particularly the synchronization process. It is enough to use 16-bit signal because for the task completion, only 10 signals are needed.

Pseudorandom sequences and orthogonal signals can be used as base for noise-like signal [7]. Pseudorandom sequences is invariant for shifting, consequently signal lag is compensate. Autocorrelation function of the pseudorandom sequences has low level of the side lobes. For a system where accurate synchronization is significant this characteristic is good. Autocorrelation function can determine desired signal when all pseudo-random sequence is received.

$$R_{XY}(\tau) = \int_{-T}^{T} X(t) \cdot Y(t-\tau)dt \qquad (1)$$

This mechanism of active interferences protection is described in details in this article [8].

3. Noise-like Signals in Meteor-Burst Communications (MBC)

Meteor-burst channel has special aspects which make it unique. Due to the fact that the reflection from a meteor-trail occurs by mirror-reflection, radio meteor possesses the property of spatial selectivity. Also one of the advantages of MBC is the possibility of using low-power transmitters. The slant range to the ionized trail which determines the transmission distance in MBC is ranging from 800 to 2000 km. The security of the meteor burst channel is provided by using a simple antenna systems (looks like TV-broadcasting antenna) which is invisible in the city. Because the reflection comes from meteor bursts, MBC can be used as a long-distance communication in conditions of a nuclear war.

The disadvantage of the meteor-burst communication is the discretion. Duration of the meteor-burst reflection is equal to (10-100) ms. Next reflection waiting time ranges from few seconds to few minutes. This problem is irrelevant if the transmitter and receiver system is equipped with devices for information accumulation. MBC provides high information security level due to spatial selectivity, low transmutation power, discretion. Interception of the transmitted data is implemented if the data transmission by MBC is known illegally. Also it must be known where to locate the receiver of the system. Using a noise-like signal may ensure the information security.

Using noise-like signals with various communication systems have many advantages. This kind of signal possesses a spectral characteristic like spectral characteristic of white Gaussian noise. Noise-like signal based on the pseudorandom sequence calls (chip). Noise like signal is a signal with a base more than 1, [9]. Receiving of the noise-like signal is possible if optimal filter is provided in the receiver. This filter and the signal must be set on the same pseudorandom sequence. Application of noise-like signals was hard earlier, but now this is possible with evolution of the computers. Spectral width of the noise-like signals depends on the pulse duration, hence the larger the pseudorandom sequence, the wider the signal spectrum.

Improving the meteor burst communication systems by applying noise-like signals will allow to increase the information security.

Meteor-burst channel has limitation from the frequency point of view. MBC frequency range is from 20 MHz to 120 MHz; on higher frequencies signal loss is observed. The best frequency for MBC is 45 MHz. Frequency characteristics of the MBC are not studied enough.

4. The use of noise-like signals in MBC

The frequency response of the reflected signal in theoretical terms is written as below:

$$A(f) = \frac{1}{f^{2.5}} \qquad (2)$$

The above equation describes that amplitude of signal ***A***, which is received on ***f*** frequency, is in inverse proportion to this frequency ***f*** raised to the power of 2.5. This equation most often had been used for a medium frequency selection of the communication system, and not for amplitude frequency response characterization. Graphical representation of the above mentioned equation (in dependence of the meteor trail type) is depicted on the Figure 2.

According to (2) if the signal bandwidth is 10 MHz, signal losses will be in 2 times on the highest frequencies compare to lowest frequencies. This feature has an influence on the transmission quality. The wider bandwidth results in more loss. It is necessary to choose the noise-like signal for transmission over the radio meteor, that must proceed from the requirements of frequency, as if to set a signal with too broad spectrum, data will be difficult.

To study the influence of the MBC frequency characteristics on the noise-like signals transmission, a chirp signal with a bandwidth of 16 MHz has been selected. The normalized signal spectrum without attenuation is shown in Figure 3.

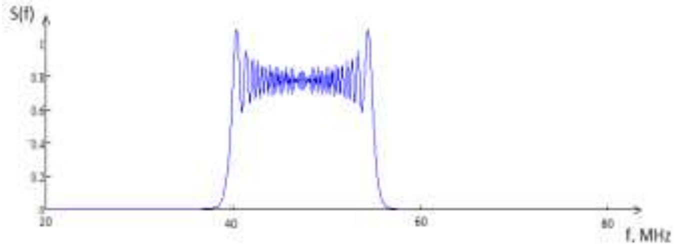


Figure 2: The spectrum of the original noise-like signal

The frequency of the signal is in the most suitable value for a MBC (45 MHz). With the passing of the signal through MBC normalized spectrum takes the following form.

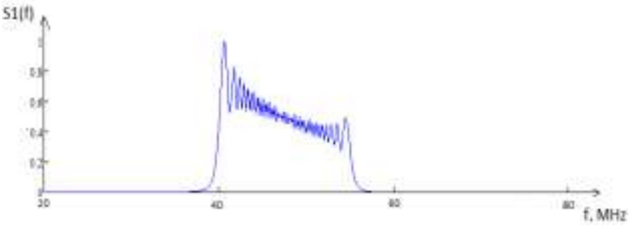


Figure 3: The spectrum of the noise-like signal passed through MBC

This model shows spread spectrum signal changes with transmitting by MBC. For more accurate researching it is necessary to perform theoretical researches.

5. Experimental Research

Ambiguousness of the frequency response is not permitted in recommended formulation wideband signals. In order to clarify the MBC frequency-domain characteristics, many experimental researches have been performed.

In 1970s such researches had been made. By way of accuracy increasing a range of the experiments to learn the frequency characteristics of the MBC was handled to increase accuracy of the meteoric-burst communication systems which are specialized on the time comparison [10].

The main researches which have been handled in the 1970s refer to the investigation of the capability to transmit noise-like signals by the meteor burst channel. The influence of the MBC on the noise-like signals quality is estimated. A signal with 800 kHz bandwidth is transmitted and its group-delay have been estimated experimentally. This research suggests that MBC has no effects on the transmitting signal with such bandwidth. Therefore this research take up the position that noise-like signals transmission through MBC is possible.

Otherwise, this research doesn't have the answer on such following questions:

1) Numerical evaluation of the frequency response of the MBC.
2) Transmission capability of the signal with 10 MHz bandwidth.

To answer these questions an experimental research is required. TV signal can be used as an experimental signal for this research.

The advantages of the TV signal use are:
- TV signal bandwidth is 8 MHz that is close to the required 10 MHz
- Special transmitter and energy expenditure are not needed.
- Permission to transmit radio-signal is not needed.
- Measurements can be performed continuously because television broadcasting is practically full-time.
- TV signal usage has a range of specialties that must be taken into account.
- TV signal spectrum is irregular and it has a variable bandwidth;
- Several transmitters can work on the same frequency channel. It can create interferences.
- TV signal which is received by MBC is rather low and that is why special equipment application is required for the signal's receiving and processing.

The answer for the stated questions could be given by either the shape of the measurement TV-line or TV picture quality control. The measurement of TV-lines contains the package of different frequency signals. The conclusion about channel's response characteristic can be made with the help of TV picture quality control.

For this research the first channel of the VHF band (49.75→56.25) MHz is the most suitable, as it is stated in [11] (where the capability assessment of the receiving TV signal transmitted by MBC is made). Transmitter of the Ostankino Technical Center (Moscow, Russian Federation) (50 kW) was chosen in analysis of transmitters which work on this frequency channel. Balakliyskiy Geophysical Complex of the Kharkiv National University of Radio electronics (BGC KhNURE) a national scientific property of Ukraine was chosen for signal reception. The main advantage of BGC is a large distance from megalopolis. It provides low noise electromagnetic environment. Long-term meteor observations and earth's ionosphere researches were performed there. Also BGC took part the International Geophysical researches in 1959.The path length between Ostankino Technical Center and BGC is about 800 km. Let's consider energy characteristics of the MBC on this path.

Meteor trails can be classified by their electron density. Electron density has influence on a signal reflection capability. Meteor trails can be low dense ($\alpha=10^{10}\ldots10^{15}$ el/m^2) and over dense meteor trail ($\alpha=10^{15}\ldots10^{18}$ el/m^2).

The equation that characterizes the power of the signal reflected from over dense trail is shown below.

$$P_r = \frac{P_t G_r G_t \lambda^2 \sqrt{\frac{4D+r_0^2}{(\sec\theta)^2}\ln\left(\frac{r_e \alpha \lambda^2 (\sec\theta)^2}{\pi^2(4D+r_0^2)}\right)}}{32\pi^2 r_1 r_2 (r_1+r_2)(1-(\cos\gamma)^2(\sin\theta)^2)} \quad (3)$$

In this equation; P_t, P_r means the power of the transmitted and the received signal respectively, G_r, G_t are the directivity factor of the transmitting and receiving antenna respectively, λ is the wavelength, D is the ambipolar diffusion coefficient, r_0 is starting radius of the meteor trail, θ is the angle of arrival of the transmitting flat wave on the meteor burst, r_e is the electron radius, α is the linear electron density per one meter, r_1, r_2 are the distances between meteor burst and the transmitting and receiving antenna respectively [1].

Preliminary evaluation of the receiving signal level according to (3) is above 20 μ*V*. It makes possible to receive TV signal using the majority of the usual TV receivers.

The spectral power density of the real TV signal is given in the Figure 4. As can be noticed in Figure 4, the voice-frequency carrier differs from video carrier by a power of 10 dB. Video spectrum is irregular and it contains spectrum parts which differ from video carrier by amplitude of 40dB.

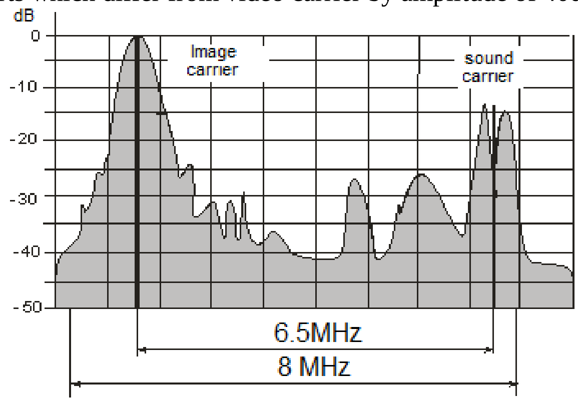


Figure 4: The TV spectrum

To define how the spectrum of the television signal that was transmitted through the MBC looks like. It is necessary to create the mathematical model of the signal given in the Figure 4. The signal must be divided into a set of points by frequency. The power of the signal transmitted by the meteor burst channel can be calculated by applying equation (4).

Therefore, the signal voltage that is received by the antenna, while the high dense burst for the video carrier is being reflected, equals to about 20 μV and voice-frequency carrier is equal to above 5 uV.

Signal that is reflected from over dense meteor trail is more preferred for frequency response characteristics, but it is necessary to get spectrum of the signal which is reflected from low dense signal. Equation which characterizes the power of the signal reflected from low dense trail is given below.

$$P_r = \frac{P_t G_r G_t \sigma \lambda^3 \alpha^2 \left(\cos(\mu)\right)^2 \exp\left(\frac{-8\pi r_0}{\lambda\left(\sec\theta\right)^2}\right)}{\left(4\pi\right)^3 r_1 r_2 (r_1+r_2)\left(1-(\cos\gamma)^2(\sin\theta)^2\right)} \quad (4)$$

σ is the scattering cross-section of an electron ($\sigma = 10^{-28}$ м^2);μ is the angle between electric field vector incident wave and trail axis [3].

The spectrum of the signal that is reflected from the low dense meteor trail can be calculated with equation (4). Receiving voltage versus frequency is shown on the Figure 5. Reflected signal from the low dense meteor trail decays more. Antenna voltage equals to 5 μV. Sensitivity level of a usual TV receiver is not enough for receiving such signal. That is why, it is necessary to use additional amplifiers to get amplified signals without distortions and they are conditioned by their own response characteristic of the meteor burst channel.

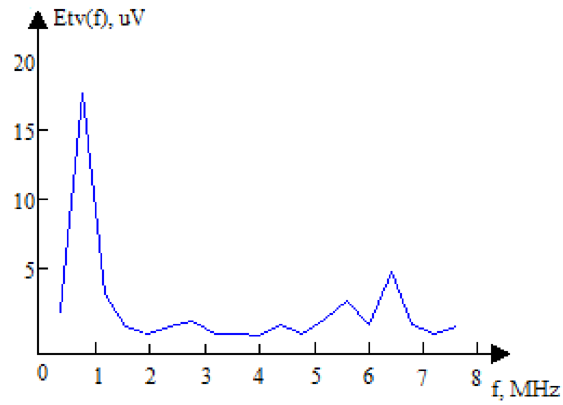
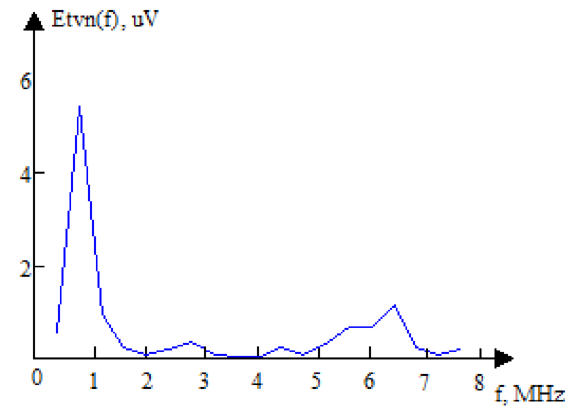


Figure 5 (a): TV signal which was reflected from over dense meteor trail



(b)

Figure 5 (b): TV signal which was reflected from low dense meteor trail

The majority of values which are used in the receiving power equation are stochastic. Linear electron density of a meteor trail is a random value. It depends on a meteoroid type and its burning conditions. Calculate minimal sensitivity of the receiver which is a function of the meteor electron density. Calculation will be performed for low dense ($\alpha=10^{10} \rightarrow 10^{15}$ el/m^2) and over dense meteor trail ($\alpha=10^{15} \rightarrow 10^{18}$ el/m^2). The voltages of the receiver antenna versus electron density of low dense and over dense meteor trails are shown in the Figure 6a and 6b respectively.

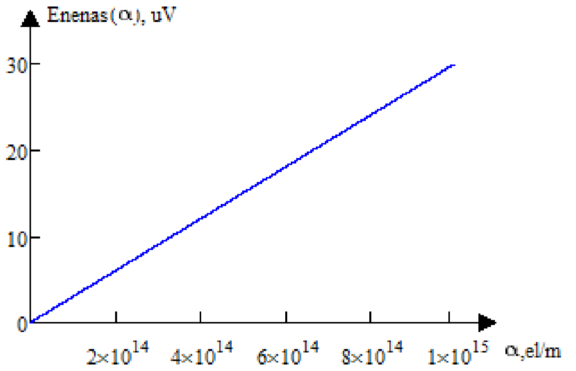


Figure 6 (a): Voltage of a received signal which was reflected from low dence meteor burst

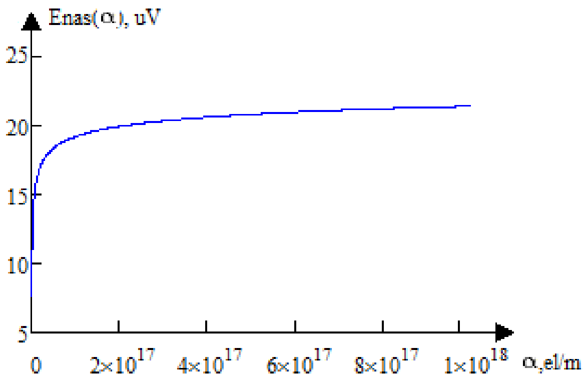


Figure 6 (b): Voltage of a received signal which was reflected from over dence meteor burst

As can be seen from Figure 6; the more electron density of the meteor trail needs less receiver sensitivity. Also, signals which are reflected from an over dense meteor trail are most acceptable for receiving since they do not need special amplifiers.

6. Conclusion

In this paper, the ways of using noise-like signals in meteor-burst communications and locations has been discussed. Due to noise-like signals characteristics, the problems associated with noise immunity, systems meteoric communication, and location can be solved. The possibility of using the spread-spectrum signals in the meteor-burst communications for back scatter sounding interferences control was described. The signals that have different characteristic are used.

According to the results obtained in this work, it is concluded that the slant range to the ionosphere (~ 2,500 km) and the slant distance to the meteor region (~ 200 km) require 10 signals for proper operation. The possibility of using noise-like signals in the meteor-burst communications system is described. From frequency characteristics of the meteor-burst channel some problems arise. To solve such problems, MBC is used to model TV signal.

Modeling results showed that, due to the unbalance of the spectral density of the TV signal, information about its spectral components near the carrier (± 0.5 MHz) can be obtained by analyzing the reflected signals from the over dense and low dense meteor. Spectral components which are offset from the carrier more than 1-1.5 MHz the analysis can performs only by the reflections from over dense trails. This aspect must be taken into account in experimental studies, which are performd by the scientists group NURE.

From modeling results, it is found that the sensitivity of the receiver must be 20 *uV* when receiving signal was reflected from over dense trail, and 5 *uV* when the signal was reflected from low dense meteor trails. Therefore, it is possible to receive the signals which were reflected from over dance trails by TV-set, while receiving signals reflected from low dense trails require high sensitivity receiver.

Accordingly, it is believed that the results obtained in this paper will help to build most optimal system for meteor burst communication using noise-like signals. Future work will focus on building of the meteor-burst system utilizing the noise-like signals and the signal decoding techniques together.

References

[1] B.L.Kascheev, "Meteor-burst communications," Kyiv UMK VO, 1989.
[2] D. W. R.McKinley, "Meteor science and engineering," Moskow Mir, 1961.
[3] B.L.Kascheev, "Meteoric phenomena in the earth's atmosphere," Moscow Nauka, 1967.
[4] D.L.Schilling, "Meteor burst communications: theory and practice," Wiley, 1993.
[5] F.Johanson, R.Mollaei, J.Thor, J.Uusitalo, "GPS Satellite Signal Acquisition and Tracking, Division of Signal Processing," Luleca University of Technology, Undergraduate Projects, 34, 1998.
[6] J.B.Y.Tsui, "Fundamentals of Global Positioning System Receiver A John," Wiley & Sons, Inc. Publication, 2000.
[7] L.Nevdiayev, "CDMA: Signals and their Properties," Network world, No.11, pp.150-157. 2000.
[8] I. E.Antipov, R. V.Shandrenko, A.I.Shkarlet, "Methods of the active radio interference protection of the meteor radiolocation system," Eastern-European Journal of Enterprise Technologies, Vol 3, No 9(69). pp. 42-46. 2014.
[9] L.E.Varakin, "Communication systems with using spread spectrum signals," Moskow: RadioISviaz, 1985.
[10] V.I.Yeliseev, "Analysis of the ionospheric influence on the chirp correlation function in meteor-burst channel Radiotechnika," Vol 39, pp.22-26, 1975.
[11] N.O.Mnerkhir, "Radar Development Method Determining Parameters meteorite Based Solution of Problem Identification," Annotation UDC 621.371.96.