Radio physical model of the meteor trail with the specular reflection point

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Introduction

In order to design meteor communication system it is necessary to have the model that allows to estimate:

- signal power in the receiving point
- dependence of the signal power on the signal frequency

Basic methods of the received signal power calculation

- Fresnel diffraction theory
- The method of the stationary phase
- The method of the phase plane

The aim

Design of the radio physical model for the estimation of the coherent and incoherent components of the signal scattered by the turbulent meteor trail

Received power from the turbulent meteor trail

The total power of the scattered signal can be described by the expression

$$P_{\Sigma}(t)=\alpha P_{coh}(\lambda,S(\tau),M_1,M_2,M_3,M_4)+\beta P_{incoh}(\lambda,\Phi(q),M_1,M_2,M_3,M_4)$$

where *a* and *β* are the influence coefficients of coherent Pcoh and incoherent Rincoh component, and $\alpha+\beta=1$;

λ is the wavelength of the signal;

S(τ) is the scattering function;

Φ(q) is generalized energy spectrum of the turbulent inhomogeneities;

q is the module of the scattering vector;

M1 is the set of parameters describing the meteor body;

M2 is the set of parameters describing the meteor trail;

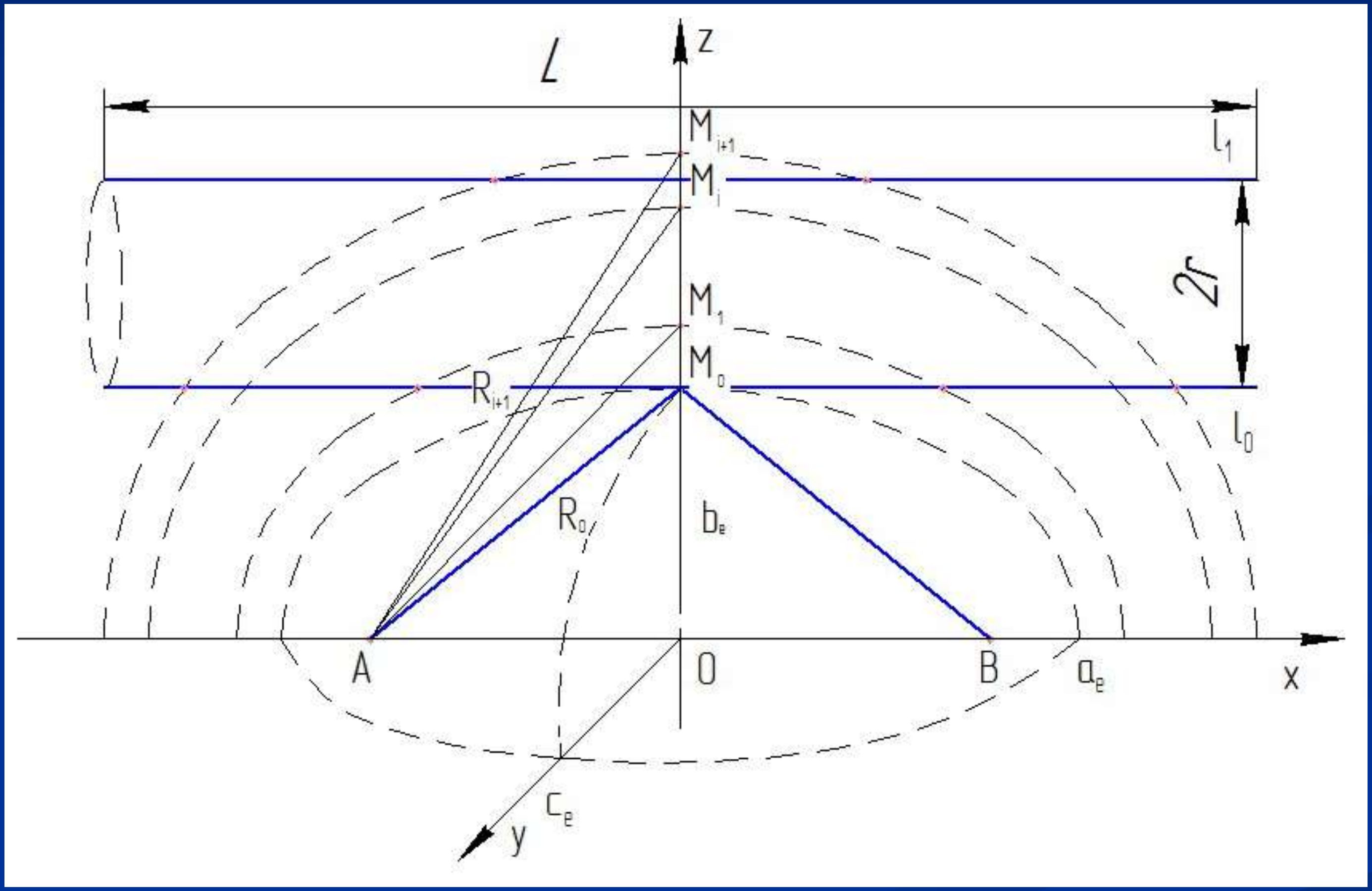
M3 is the set of parameters describing the mutual arrangement in space of radio and meteor trail;

M4 is the set of parameters describing the parameters of the radio.

Basic differences

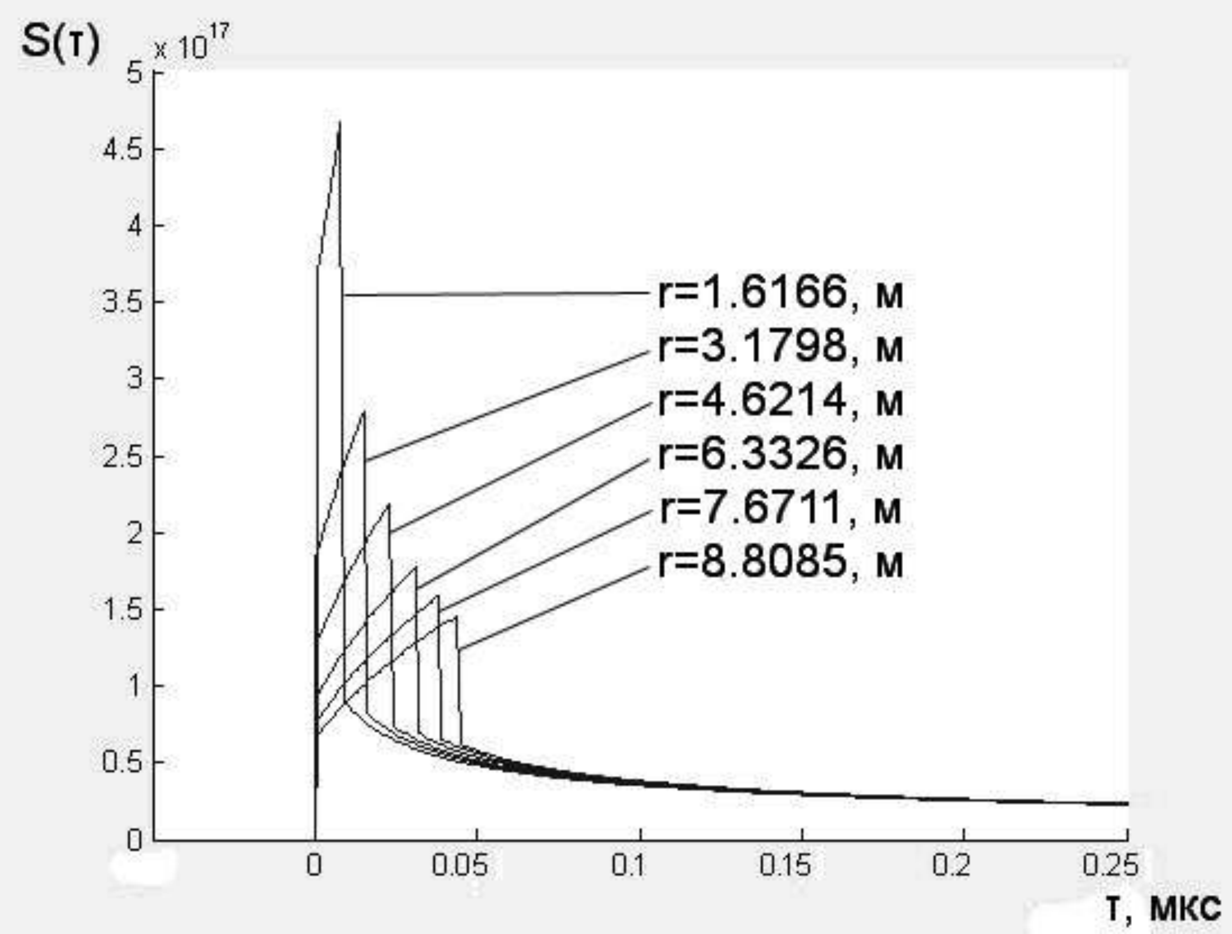
1. Coherent component of the scattered signal estimates using scattering function of the meteor trail (average pulsed response characteristic of the channel). Using of this function for calculating the mean value of coherently scattered power allows to consider the influence of the all meteor trail length. Convolution of the signal with the scattering function of the channel defines the shape of the signal at the receiver input, which allows to estimate distortions and to choose the signal parameters providing enhancing reliability of information transmission in a frequency-selective fading meteor channels.
2. During the calculation of the incoherent component is taken into account peculiarities of the energy spectrum of turbulence inhomogeneity, which determines the dependence of the scattered signal frequency.

Coherent component of the scattered signal estimation



Calculation of the meteor trail scattering function

Meteor trail scattering function



Scattering function of the meteor trail

Signal at the reception point

The signal at the reception point defined by the regular component can be represented by convolution integral

$$\tilde{s}_{reg}(t)\cdot e^{-i\omega_0 t} = \sqrt{E_t}\int_{\tau_{min}}^{\tau_{max}}\sqrt{S(\tau)\cdot\tilde{f}(t-\tau)\cdot e^{-i\omega_0(t-\tau)}}\,d\tau$$

where $E_T = P_S \cdot T$ is the signal energy at the observation interval T,

τ_{min}, τ_{max} is the interval delay in the scattering,

$\tilde{f}(t)$ is the complex envelope of the signal emitted at a frequency

Coherent component of the scattered signal

The energy of the signal at the observation interval is

$$E_{reg} = T \cdot \tilde{s}_{reg}(t) \cdot e^{-i\omega_0 t} \cdot \tilde{s}^{*}reg(t) \cdot e^{i\omega_0 t} = T \cdot \tilde{s}_{reg}(t) \cdot \tilde{s}^{*}reg(t)$$

$$P_{coh} = \tilde{s}_{reg}(t) \cdot \tilde{s}^{*}coh(t)$$

Incoherent component of the scattered signal

$$P_{incoh} = \Phi_{\varepsilon}(q) \cdot \int_{\tau_{\min}}^{\tau_{\max}} S(\tau)\, d\tau$$

$$\Phi_{\varepsilon}(q) = \frac{2\Gamma(p+0.5)}{\pi^{1/2}\Gamma(p)} (\Delta\varepsilon)^2 \frac{l}{(1+q^2 l^2)^{(p+1)/2}}$$

where $(\Delta\varepsilon)^2$ is the fluctuations intensity of ε,

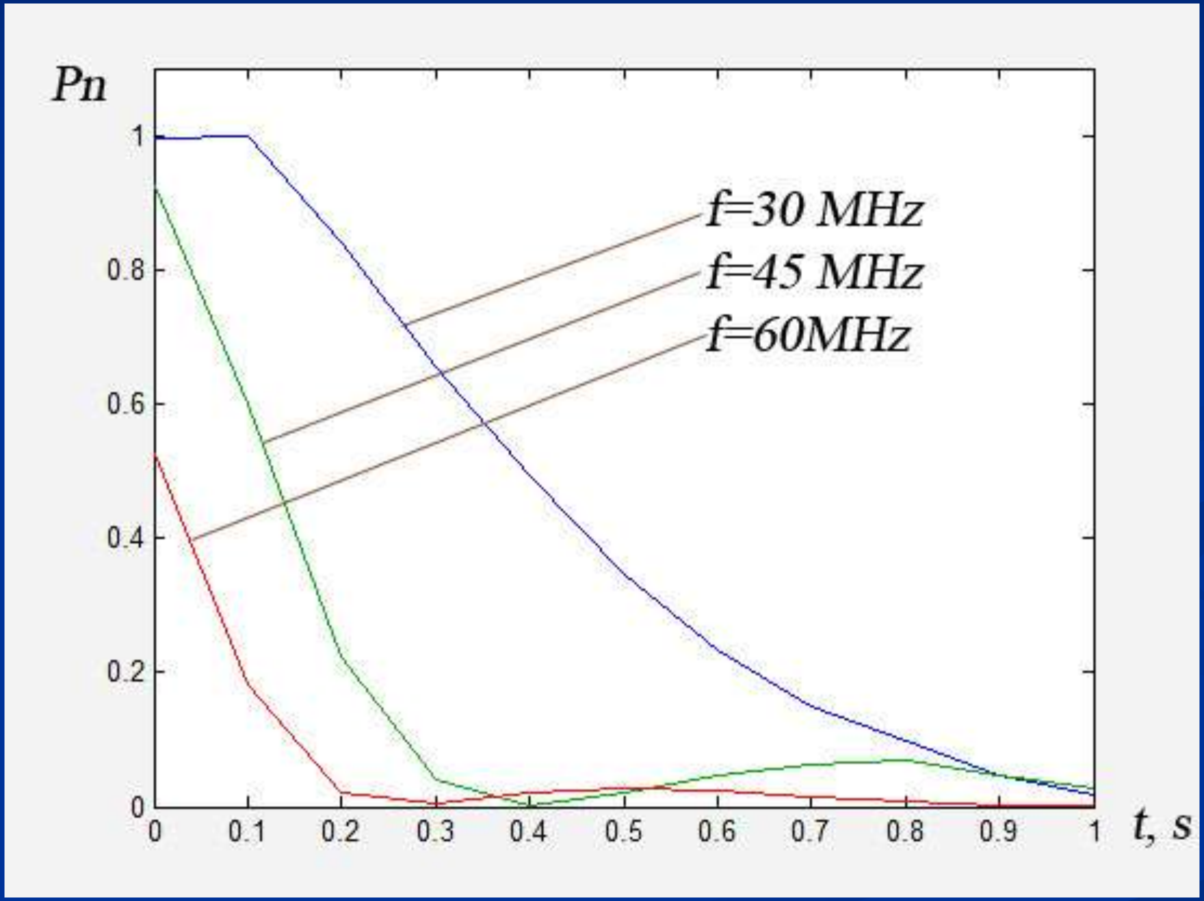
p is the index of a generalized function,
l is the scale of the turbulent inhomogeneities,
Γ is gamma function

Received signal power

The power of the scattered signal can be described by the expression

$$P_{\Sigma}=\alpha(\tau)\cdot P_{coh}+\beta(\tau)\cdot\Phi_{\varepsilon}(q)\cdot\int_{\tau_{\min}}^{\tau_{\max}}(\tau,t)\,d\tau$$

The intensity of the received signal on time



Variation of the received signal power in time

Conclusions

- Proposed radio physical model allows estimating coherent and incoherent parts of the signal power scattered by the turbulent meteor trail. Calculated scattering function provides the ability to estimate the signal waveform at the receiver input and to choose parameters of the radio, providing increase reliability of information transmission by the meteor radio channel.
- Generalized spectrum using and the choosing of the coefficients a and β allow to reconcile obtained data on the frequency dependence of the scattered signal with the experimental observations. The presence of the incoherent component of the signal scattered by the permittivity inhomogeneities of the turbulent origin allows justifying the possibility of signal observing at the long distance from the reception point.

Thank you for your attention!

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