TECHNICAL NOTE

SIGNAL OPTIMIZATION DURING RADIO LINKS BETWEEN A TRANSMITTER AND A RECEIVER LOCATED IN ADJACENT MATERIAL MEDIA WITH DIFFERING OPTICAL DENSITIES

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Abstract Signal optimization is affected during radio links between a transmitter and a receiver located in adjacent material media with differing optical densities. The optimization is carried out via the automated control theory method. The radio signal obtained after the optimization is coordinated with the two media's electrical characteristics simultaneously; and this enables low power and small antenna of the transmitter, on the one hand, and low sensitivity of the receiver, on the other.

Key Words Radio, Signal, Optimization, Optical Density, Automated Control

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INTRODUCTION

When radio links are affected between a transmitter and a receiver located in adjacent material media with differing optical densities, there are problems in the coordination of the radio signal with the different electrical characteristics of the two media.

This problem has been investigated in depth in relation to the Sanguine Project [1] which includes a system for affecting of global radio links with submarines, the transmitter being located on shore (in the atmosphere). During the investigation the graph of the dependence of transmitter output power P on the radio signal carrier frequency with parametric variation the length of both the transmitting antenna and the distance between the transmitter and the receiver is plotted. From the viewpoint of classical radio engineering methods, with the conduct of this investigation the optimization related to the above problem can be considered to be exhausted, i.e. it can be assumed that there are no other variants. A proof of this could be the fact that despite the excessively high stationary power of the transmitter (10 MW) and the excessively large antenna (with a total length of 2000 km), the Sanguine Project was carried out in the US. The history of radio engineering does not mention any other such enormous and costly radio engineering facility. Later a similar system was created in USSR.

However, the investigation of the above problem can be continued using methods which are not traditional radio engineering methods, namely, the Automated Control Theory.

According to the Automated Control Theory, the methods which can be used or optimization in this particular case are the following:

1. Variation Analysis Method - suitable for continuous functions with few variables,
2. Extremum Method - suitable for discrete functions and "partially smooth" functions,
3. Dynamic programming Method - Suitable for functions with a large number of variables and for systems with feedback, and
4. Finite Element Method - suitable for functions defined in the n-dimensional space and with additional conditions for test functions.

The Variation Analysis Method proves to be the one most suitable for optimization.

It is known from the Theory of Radio Wave Propagation that the intensities of the electrical field on both sides of the atmosphere/sea water boundary layer can be described as:

$$E_{2z} = 5.5*10^{-11} \frac{E_{1z}}{\sigma} \cdot f \qquad (1)$$

where E_{1z}, E_{2z} are the effective values of the vertical components of the electrical field in the atmosphere and the sea water, respectively, σ is the sea water electrical conductivity, and f is frequency.

In accordance with the variation analysis, in order to have an extremum of E_{2z}, the subintegral function F_v should meet the Euler equation [2]:

$$\frac{\partial F_v}{\partial E_{1z}} - \frac{d}{dt}\frac{\partial F_v}{\partial \dot{E}_{1z}} = 0 \qquad (2)$$

where $\dot{E}_{1z}$ is the first derivative of E_{1z} with respect to t.

Thus, the only possibility of obtaining an extremum of E_{2z} is measuring the frequency [2].

The result obtained is extremely important, and it shows that a maximum of E_{2z} can be obtained by a low frequency sinusoidal variation of the carrier frequency of E_{1z}.

On the basis of a specified amplitude E_{1z} and the particular values, using (1) we can determine the value of E_{2z}.

In particular, the synthesis of the radio signal should be made by the following algorithm: in the transmitter the oscillation with a high carrier frequency should be frequency - modulated by an auxiliary low frequency sinusoidal oscillation (with a frequency below 500 Hz). Then, in accordance with (1), frequency detection will take place in the atmosphere/sea water boundary layer, and from this layer to the transmitter the auxiliary oscillation will be also the carrier oscillation. The oscillation corresponding to the information being transmitted will modulate in advance the auxiliary oscillation via some of the known modulation types.

Since the carrier oscillation of the transmitter will have high frequency (considerably higher than the Sanguine Project frequency - 500 Hz), this oscillation can be emitted on a high level, with low transmitter power and a small antenna. This in particular would mean that the threshold of noise-immune frequency detection of the boundary layer could be easily exceeded.

Besides, in accordance with the data obtained above, the transmitter can have low sensitivity.

The sea water is a low - frequency filter with respect to the radio signal. In accordance with the Theory of Radio Signals this means that to replace the high carrier frequency by a lower one in the above-mentioned conditions, phase modulation could be used as well.

Except for radio links, the results obtained can also be used for radio location of objects in material media with different optical densities.

REFERENCES

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2. Schecher R., "The Variational Method in Engineering", New York, N.Y., 1961.