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ABSTRACT

of the dissertation for the degree of doctor of philosophy

INCREASING THE CAPACITY OF TERRESTRIAL MULTI-CHANNEL CELLULAR TELEVISION BROADCASTING SYSTEMS

Speciality: 3325.01-“Telecommunication technology”

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GENERAL CHARACTERISTICS OF THE WORK

The urgency and status of the problem. The capacity, signal/interference ratio, and data transmission accuracy of each communication or broadcasting system are closely interrelated parameters. At present, in the terrestrial television (TV) broadcasting and distribution network is widely used a new type of broadband radio access network, which is distinguished by its high speed and high integration of services. These types of systems are commonly used to solve the "last mile" problem of communication systems. A number of known advantages, along with other communication services, have allowed them to be used as the ultimate link of terrestrial TV broadcasting.

Various modifications of such systems are already in operation. The commonalities allow us to combined them under one name, to generalize the scientific problems encountered during the application, and to reveal the commonality of their solutions.

The considered systems operate at extremely high frequencies and have a very wide spectrum of signals and high transmission speeds. Increasing the capacity of such systems is closely related to reducing interference signals. Due to the high frequency, there are no external interferences on the air. Therefore, it is very important to pay attention to the interferences created by system itself (intra-system interferences). In addition, the broadband signal causes cross- interferences. Such interferences in the transmitter-receptor tract appeared as amplitude-amplitude (AM-AM) and amplitude-phase (AM-FM) transitions. Reducing these types of interferences also has a significant impact on the system's capacity.

Among the intrasystem interferences, interferences related to the network topology are also important. Therefore, proper frequency-terrestrial planning, proper selection and management of power in the direct and reverse channels are also important in the construction of the network. The influence of the modulation method on the service area of the stations and, consequently, on the level of potential interference in the system is known. Therefore, the choice of right modulation method and its management during operation in such systems can significantly affect the capacity of the system.

Based on the above mentioned, it is safe to say that the topic of the dissertation is relevant.

Object and subject of research. The object of research in the dissertation is a multi-channel broadband cellular radio access network used as the last link ("last mile") of the terrestrial TV broadcasting and distribution network. The subject of the research is to increase the capacity of the multi-channel broadband cellular radio access system used as the last link of the terrestrial TV broadcasting and distribution network.

The main purpose of the dissertation and main issues of the research. The main purpose of the dissertation is to increase the capacity of the cellular multi-channel radio access systems used as the last link of the TV broadcasting and distribution network by reducing cross-interferences and interferences related to the network topology.

The following issues have been set and resolved to achieve this goal:

- the sources of interferences arising during multi-channel transmission are classified and the causes of these interferences are analysed;

- one-dimensional statistical characteristics of multi-channel TV broadcast signal were derived and the obtained results were compared with similar characteristics of terrestrial TV broadcast signal;

– statistical characteristics of AM-AM type combination interferences were obtained, taking into account the amplitude characteristics of the power amplifier of the broadband TV broadcast signal assembled on the transistor and the travelling wave tube;

- taking into account the known phase-amplitude characteristics of a broadband power amplifier, an expression is derived for the calculation of combination interferences caused by AM-FM transitions;

– when the TV broadcast signal is transmitted by QPSK (Quadrature Phase Shift Keying) modulation, a single coherent optimal reception algorithm and a schematic of the corresponding receiver are built under the influence of numerous interferences concentrated over the spectrum and against the background of fluctuation noise;

- in the direct channel of the LMDS (Local Multipoint Distribution System) system, a scheme of automatic switching of the modulation method based on the power of measured signal is established;

- the dependence of the measurement accuracy of the power of the pilot signal (transmitted from the subscriber station (SS) on the base station (BS)) under the influence of fluctuation noise and extreme broadband interference on the probability of tolerable errors has been removed;

- on the example of Baku city and the Absheron Peninsula the possibilities of building a cellular TV broadcasting network, the principles of selection of parameters and the rules of using the booster are shown.

Research methods. Theoretical and experimental research methods were used in the dissertation.

İn the theoretical research has used digital signal processing, signal conversion theory, optimal radio reception theory, information theory, probability theory, mathematical statistics, differential and integral arithmetic.

In order to verify the theoretical results, obtained in the dissertation, as TV broadcasting and distribution network the distribution network of cable TV of our country was selected and relevant experimental research were conducted. The network of cable broadcasters "Connect TV" was used as a distribution network of cable TV, MMDS (Multichannel Multipoint Distribution System) and LMDS stations installed as a main station on Baku TV tower, a booster was placed in Zykh station.

The accuracy of the obtained results was also verified by numerical calculations and production tests.

The main issues raised in the defence. The main issues raised in the defence are:

1. Mathematical expressions for the calculation of AM-AM type cross-interferences for different amplitude characteristics of broadband power amplifiers of the TV broadcast signal assembled on various active elements and operated in different modes.

2. Mathematical expressions for the calculation of AM-FM type cross-interferences based on the phase-amplitude characteristics of broadband power amplifiers of TV broadcast signal.

3. The method of reducing nonlinear distortions by selecting the levels of subcarriers and the mathematical expressions derived for the relevant calculations.

4. Algorithm of optimal coherence reception of QPSK modulated TV broadcast signals at the influence of the interferences concentrated over the spectrum and at the background of fluctuation noise and scheme of its receiver.

4. Scheme of adaptive modification of the modulation method depending on the measured power of the pilot-signal or the signal/interference ratio in the LMDS type cellular TV broadcasting network.

5. The construction of a cellular TV broadcasting network in the Baku city and Absheron Peninsula, the selection of parameters and the application of the booster.

Scientific novelty of the results obtained in the dissertation. The scientific innovations obtained in the dissertation mainly consist of the following:

1. Expressions are derived to calculate two-dimensional probability characteristics of AM-AM type cross-interferences and the power of AM-FM type cross-interferences, for different modes of power amplifiers of broadband group TV broadcast signals, assembled on different active elements and expressions are derived to calculate reduction of nonlinear distortions by selecting sub-carrier levels.

2. Under the influence of large number concentrated over the spectrum interferences and on the background of fluctuation noise, a single optimal coherent receiver circuit of phase-amplitude modulated TV broadcast digital signals was constructed.

3. A scheme for adaptive selection of a compromise between the power of the BS radio transmitter and the signal modulation method in the direct channel of the LMDS system, was constructed and for this purpose for the pilot signal from AS one-dimensional statistical characteristics at the output of the characteristic circuits of the BS receiver were determined.

4. During the adaptive change of the signal modulation method in the BS radio transmitter of the LMDS system, the dependence of the accuracy of measurement of the signal power or signal/interference ratio on the allowable value of the error probability is obtained.

5. The method of application of the main radio transmitter and booster of the cellular TV broadcasting network in the territory of the Baku city and Absheron Peninsula and the method of selection of parameters are substantiated.

Scientific and practical significance of the dissertation. Scientific and practical significance of the dissertation is as shown below:

1. The analysis of the air-cable TV distribution network allows to choose the most suitable values of the network parameters, to identify

the characteristic distortions and their sources, and to improve the main quality parameters of the network.

2. Reducing the level of AM-AM and AM-FM type cross-interferences method can be used to reduce intra-system interferences in the transmitter-receiving tract of all broadband communication systems.

3. Adjusting the power of the BS radio transmitter or adapting the modulation method by measuring the power or signal/interference ratio through the feedback loop allows the interference in the direct channel to be minimized.

The results obtained in the dissertation were used in the construction of air-cable TV distribution network in our country.

Personal contribution of the author. The scientific issues raised in the dissertation and the main results obtained independently by the author. The results of the work are reflected in the author's articles published in our country and in foreign scientific and technical publications.

Approbation of the dissertation. The main scientific and practical provisions of the dissertation were discussed and appreciated at scientific and technical conferences of Azerbaijan Republic, at international scientific and technical conferences (Baku city, 1998, 2001, 2005, 2008, 2009, 2011 and 2021 years; Moscow city, 2011, 2015 years; Samara city, 2016 year), in the seminars of the teaching staff of the Azerbaijan Technical University (2000...2014 years).

Publication of the results of the work. 23 scientific works, which reflect the content of the dissertation and their results, were published in national and foreign scientific and technical publications. Eleven of them are articles published in scientific publications of the Azerbaijan Republic, other scientific articles published in journals: one in «Электросвязь», one in «T-Comm», one in «Системы синхронизации, формирования и обработки сигналов» (all three in Moscow city), one in «Телеспутник» (St. Petersburg city), and seven are materials of international and Azerbaijan Republic scientific-technical conferences.

The organization where the dissertation work is performed. The dissertation was completed at the Azerbaijan Technical University.

The structure and scope of the work. The dissertation consists of 158 pages of computer text in A4 format, including an introduction, four chapters, results, a list of references and appendices, 27 figures, 7 tables, list of references used in 158 titles and 2 appendices. Introduction to the dissertation consists of 11 pages in A4 format (number of characters 19043), 1 Chapter 24 pages (number of characters 30780), 2 Chapter 24 pages (characters number 31298), 3 Chapter 36 pages (number of characters 41614), 4 Chapter 28 pages (number of characters 37026), the result is 4 pages (number of characters 5350), “Basic notation” is 3 pages (characters number 1739) and main part of dissertation consists of 130 pages of computer text in A4 format (number of characters 166850).

MAIN CONTENT OF THE DISSERTATION

The introduction substantiates the relevance of the dissertation topic, explains the purpose and main objectives of the research. The scientific novelty of the work and the practical significance of the obtained results were presented. Important results, suggestions and recommendations on the application of the teaching process and production are given.

In recent years, to solve the "last mile" problem the known advantages of the latest technologies, such as MMDS, LMDS and MVDS (Multipoint Video Distribution System), have led to their widespread use (Table 1). At present, these systems are used in the air-cable distribution networks of cable TV in the territory of our country.

The **first chapter** of the dissertation, "Critical analysis of methods to increase the capacity of terrestrial multi-channel cellular television broadcasting systems" is devoted to the analysis of methods to increase the capacity and efficiency of broadband radio access networks used in TV broadcasting and distribution networks. It can be seen from Table 1 that there are different options for the systems under consideration. The common features of these systems are broadband signals, building a network on a cellular basis, operation in the extreme high frequency range, highly integrated services, and the use of known multi-parameter modulation methods. These similarities suggest that the problems encountered during their application will also be common. However, due to differences in the radius of the cell and the operating frequencies, there are some differences between these systems that must be taken into account when applying the systems (see Table 1).

Architecture of simplex and duplex MMDS and LMDS radio networks used in TV broadcasting and distribution networks, classification of distribution network, sources of main special interferences,

Table 1

Key features and advantages of MMDS, LMDS and MVDS systems

N0	MMDS	LMDS	MVDS
1	Transmission speed is high	Transmission speed is higher.	Transmission speed is very high.
2	It is a wireless system, so there is no need to use expensive cables.	It is a wireless system, so there is no need to use expensive cables.	It is a wireless system, so there is no need to use expensive cables.
3	Data confidentiality can be ensured.	Data confidentiality can be ensured.	Data confidentiality can be ensured.
4	Networking can be done quickly.	Networking can be done quickly.	Networking can be done quickly.
5	The price / production ratio is remarkable. Operating costs are very small.	The network is set up in a very short time. The price is cheap. It can be expanded or removed without incurring large costs.	Initial installation is simple, quick and relatively inexpensive. It can be expanded or removed without incurring large costs.
6	Subscribers can be relocated without incurring additional equipment costs.	Subscribers can be relocated without incurring additional equipment costs.	Subscribers can be relocated without incurring additional equipment costs.
7	There is an opportunity to use passive and active repeaters in order to provide a reliable reception area in the territory of urban buildings.	There is an opportunity to use passive and active repeaters in order to provide a reliable reception area in the territory of urban buildings.	There is an opportunity to use passive and active repeaters in order to provide a reliable reception area in the territory of urban buildings.
8	It is possible to receive multi-channel terrestrial television signal.	It is possible to receive multi-channel terrestrial television signal.	It is possible to receive multi-channel terrestrial television signal.
9	It is less environmentally dangerous because it processes weak signals with relatively high frequencies.	It is almost environmentally safe because it processes weak signals with high frequencies.	It is environmentally safe because it processes very weak signals with very high frequencies.
10	There are few gap zones.	Gap zones are almost non-existent.	Gap zones are almost non-existent.

features of channel type and multi-channel radio transmitters used in BS, methods of correction of non-linear distortions arising at transmission of TV broadcasting signals on this type of TV distribution network are analysed. Possibilities of application of multi-channel broadcasting systems in the distribution network of cable TV have been studied.

The similarities between the existing systems and the problems encountered during their application, the general ways to solve these problems are shown (Table 2).

Table 2

Scientific and technical problems arising in cellular broadband radio access networks and general ways of their solution

N0	The name of the problem	Emerging effects or interferences	Preliminary version of scientific and technical activities
1	Nonlinear processes occurring in the active element	Amplitude-amplitude transitions	Application of correction circuits, mode selection
		Amplitude-phase transitions	Application of correction circuits, mode selection
		Other intermodulation interferences	Application of correction circuits, mode selection
		Blocking weak signals with powerful signals	Application of correction circuits, mode selection
		Decreased output power in amplifier mode	Application of correction circuits, mode selection
2	Arising of the multipath reception condition	The fall of reflected waves to the input of the radio receiver	Blocking the input of the radio receiver due to guard interval, use of reflected wave power, application of better reception methods
3	Occurrence of frequency selective attenuation	Attenuation and depressions in different frequency members of the signal	Application of OFDM modulation, corrections on frequency members, application of better reception methods
4	Interaction of BS radio transmitters	Interference between signals of BS radio transmitters on direct channel	Selection of BS coordinates, selection and adjustment of radio transmitter power, changing of modulation method

In this chapter explains the causes of intermodulation interferences in the considered systems. It is shown that non-linear distortions occur as a result of non-linearity of the static and dynamic characteristics of electronic devices, non-linear dependence of its reactive parameters, in particular, the capacity of the collector junction on the current, as well as the presence of amplitude-phase conversion in the input circuit of the electronic device, the elimination of which leads to an increase in the quality of the system

It justifies the correct choice of the research object of the dissertation and shows the importance of its research. From the mentioned scientific and technical problems, the most urgent ones were selected, substantiated and general ways of their solution were shown. This chapter provides the mathematical apparatus to be used in the next chapters of the dissertation, substantiates its adequacy, formulated and substantiates the problems to be solved in the later chapters of the dissertation.

In the **second chapter** of the dissertation, entitled "Reduction of combination interferences in the transmitter-receiver tracts of broadband signal transmission systems", scientific research was conducted to reduce AM-AM and AM-FM intermodulation interferences, and new scientific results obtained on this problem have been shown.

Using the characteristic function and taking into account the known distribution model of brightness on TV images, the main statistical parameters of the multi-channel TV broadcast signal were determined, and the purpose of using these parameters was shown. A mathematical expression for the characteristic function $\theta_{1\Sigma}(v)$ of the voltage of a multi-channel TV broadcast signal is derived for the case when the brightness on TV images have the inverse proportional distribution:

$$\theta_{1\Sigma}(v) = \frac{U_{max}^{N} e^{-iNvU_{max}\alpha_0}}{\left(ln \dfrac{\alpha_0 + 1}{\alpha_0} \right)^{N}} \left(ln \frac{\alpha_0 + 1}{\alpha_0} + ivU_{max} \right)^{N}, \quad (1)$$

here U_{max}– is the voltage, corresponding to the maximum brightness on the images, N – is the number of programs, and α_0 – is an experimentally fixed quantity that characterizes the image.

Then, using the cumulative function, the mean value and dispersion of the total signal of the multi-channel TV broadcast was determined and compared with similar parameters of the terrestrial TV broadcast signal, the characteristic differences were revealed.

In order to study the distortions in the form of AM-AM type transition, two-dimensional probability characteristics (correlation function and energy spectrum) of the output random process were determined, taking into account the form of amplitude characteristics of different modes of amplifiers on different active elements. These parameters were studied separately for soft and hard restriction modes. Knowing that when the amplitude characteristic is approximated by the Newton's binomial, all even members of the series are equal to zero, and based on the fact that the 5-th and higher order nonlinear products are very small, a mathematical expression is derived to calculate the power of the correlation function, energy spectrum, and power of combination interferences P_k of the output random process when to the input is fed normal stationary random process:

$$P_k = 6a_3^2\sigma^6\sqrt{\frac{2\pi}{3}}\frac{1}{\sqrt{-R_S''(0)}}, \qquad (2)$$

here a_3 – the coefficient of the 3-rd degree member of the binomial, σ^2 – the dispersion of the input random process, $R_S''(0) > 0$ – is the second-order derivative of its correlation function.

Using the known expression of the phase-amplitude characteristic for semiconductors, the distribution model of amplitude of the combiner members was determined when the amplitude of the random process at the input is determined by Relay's model, based on which the dispersion of the output process was determined. A mathematical expression was derived to calculate the power of the combination interferences created by the AM-FM transitions.

In addition, a mathematical expression was derived to calculate the power of the combination interferences for the phase-amplitude characteristic obtained when the phase slip jumps were combined with normally distributed phase fluctuations.

In this chapter, the maximum value of the transition interferences is determined, knowing that the signal power at the output of the channel is determined by the required value of the signal/interference ratio. Here, a mathematical expression is obtained to determine the levels of the sub-carriers that allow the reduction of transition interferences, using the expression derived for the peak factor of the multi-channel TV broadcast signal:

$$A_0 = \frac{2K_{pik}A_{max\,0}}{\sqrt{\dfrac{\alpha\pi}{arctg\,\alpha\omega_{max}}}}, \qquad (3)$$

here A_{max0} – is the effective value of the luminance signal, ω_{max} – is the maximum angular frequency of the video signal, $\alpha = 4\times10^{-6}s$ – is a constant quantity, K_{pik} – is the peak factor of the channel signal.

It has been shown that by correctly selecting the levels of the sub-carriers, it is possible to reduce the total power of the group signal and therefore the level of nonlinear distortions.

The **third chapter** of the dissertation "Selection and adaptive control of radio transmitter power and modulation type in the direct channel of the multi-channel cellular TV broadcasting and distribution network" is devoted to the selection and management of a compromise between the modulation method and the power of the transmitter in direct channel at a certain accuracy of information transmission on cellular TV broadcasting and distribution network. Here, in LMDS and MVDS (Multipoint Video Distribution System) systems, the issues of automatic switching of used QPSK and M-QAM (Quadrature Amplitude Modulation) modulations from one to another were used to keep the noise immunity within the allowable range depending on the power of the signal at the receiving point were studied.

It is known that potential noise immunity is provided by an optimal radio receiver. An optimal reception algorithm must be developed to build the scheme of such radio receivers. For this purpose, the conditions of reception must be determined. Here it is considered that the frequencies of interferences caused by nonlinear effects are combinations of signal frequencies, so the total interferences can be considered quasi-harmonic and can belong to the group of interferences collected according to the spectrum. Taking into account these conditions, the optimal radio reception of the considered digital signal is brought to the algorithm of binary signal differentiation in the background of fluctuation noise and under the influence of the collected interferences according to the spectrum.

In order to ensure the potential noise immunity in this chapter, a single optimal coherent reception algorithm of the symbols in the specified reception conditions was developed, and on the basis of this algorithm, a two-channel scheme of that optimal receiver was constructed. The radio receiver consists of quadrature and in-phase processing channels. The obtained radio receiver was compared with similar optimal radio receivers given in different literature, and the similarities, differences and advantages of the considered radio receiver were shown.

Knowing the minimum required power of the received signal, it is possible to increase the noise immunity of the system by selecting the power of the transmitter and the type of modulation. In the modern scientific and technical literature in this area, the latest option is to apply two different multi-parameter modulations in the direct channel of the LMDS system. In this case, two types of modulation were applied in a multi-channel radio transmitter of the same BS, depending on the distance from the transmitter to the radio receiver. QPSK modulation was used for farther subscribers, and M-QAM modulation was used for closer subscribers.

Noise immunity in QPSK modulation is higher than in M-QAM modulation. Therefore, the signal at the input of farther radio receivers is considered to be weaker, and it is considered expedient to apply modulation that provides greater noise immunity for farther subscribers in order to keep the noise immunity stable.

However, fades occurring during the propagation of radio waves in space are random. Therefore, selecting the type of modulation based on distance alone may not give accurate results. In other words, the assumptions about the value of power at the receiving point and the required value of the accuracy of data transmission by changing the type of modulation may not be justified. For this reason, we have proposed and applied to quickly determine the value of power at the receiving point and to provide the required value of noise immunity, provided that the power of the BS radio transmitter is kept constant.

Our purpose is to select the power and the appropriate modulation type on the channels of the BS multi-channel radio transmitter to ensure the required noise immunity in the direct channel of the LMDS-type broadband radio access network and to adjust these parameters depending on the current fading so that the error probability does not exceed required value. The method of power regulation is not new, and this method is widely used in cellular telecommunication. Algorithms and schemes of power regulation in the direct and reverse channels are given in the literature.

Down stream of the LMDS system structure differs from the structure of the transmitter side of a conventional digital TV broadcasting system by the application of two different modulators at the output. However, the transition from one modulation method to another is not controlled here, it is predetermined by the location of subscribers. This cannot be considered appropriate for the reasons already mentioned. In order to change the modulation method according to the signal of the control circuit, it is necessary to choose the most suitable one from the known control circuits.

Models and methods of management are given in communication theory. Management can be deterministic or stochastic. Both the controlled object and the measuring block are affected by external interferences. In this condition, a stochastic control scheme has been proposed in communication theory. Here, the control algorithm of the system is determined according to the given characteristics of the controlled system, the probability characteristics of external interferences and measurement interferences (Figure 1). The transition from 16-QAM to QPSK and vice versa is based on the results of the processing of the signal received from the feedback circuit. The control circuit measures the pilot-signal level or pilot-signal/noise ratio. The pilot signal received from the subscriber via the feedback loop is narrow-band and can be separated by a notch filter. The signal and the noise in this band are then separated by a bandpass filter and passed to the signal/noise ratio (SIR) measurement circuit. In this circuit, first the pilot signal is subtracted from the total signal, and then the signal/noise ratio is measured.

An expression was derived for the dependence of the error probability on the energy parameter for optimal coherent reception during automatic switching of QPSK and M-QAM modulations from one to another, provided that the power of the BS radio transmitter is kept constant. An appropriate graph was constructed (Figure 2). It is clear from the graph that although the application of this method does not increase the power of the BS radio transmitter, the probability of errors is not less than the required value (in this case, when the energy parameter $h_b^2 \geq 10$, $p_s \leq 1 \cdot 10^{-5}$).

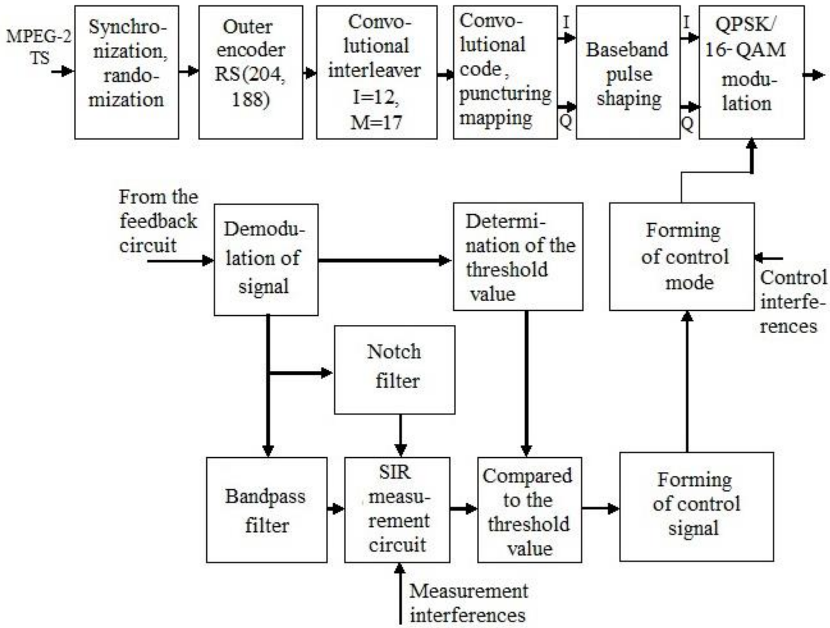

Figure 1. Structural scheme of adaptive management of the modulation method on the down line of the LMDS system

A known model was used to estimate the attenuation that occurs during the propagation of radio waves in space, and the power at the receiving point was calculated. $L = L_{tr} L_2$ is general attenuation of the signal at propagation, here L_{tr} – the attenuation of the signal along the propagation path, L_2 – are additional power attenuation on the radio line.

We have proposed and applied 64-QAM modulation at $L < L_3$, 16-QAM modulation at $L_2 \geq L \geq L_3$ and QPSK modulation at $L > L_2$.

It has been proven that the application of this method increases the energy efficiency of the system. Energy efficiency is also affected by the allowable value of the error probability and the number of M-QAM modulation positions. This efficiency is greater when the probable value of errors is high. The increase in the number of M-QAM

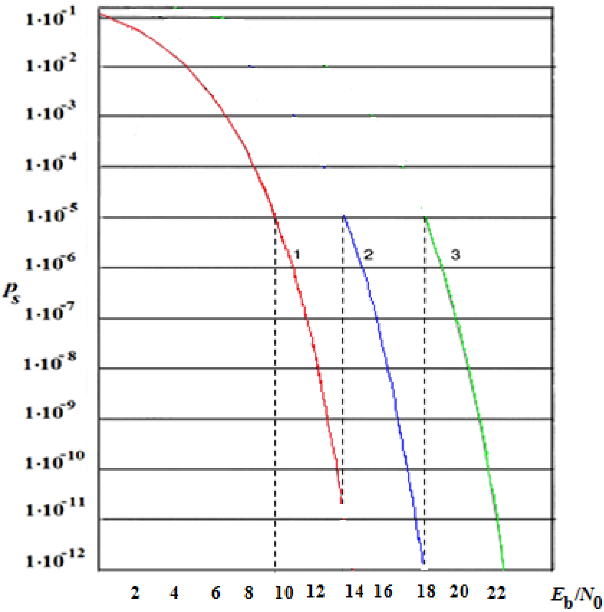

Figure 2. Dependence of the error probability on the ratio E_b/N_0 when changing the modulation method

modulation positions leads to a relative reduction of energy efficiency. For example, the following mathematical expression is derived to increase this efficiency with the transition from 16-QAM to QPSK

$$\beta_i = \sum_{i=1}^{L_k} \left(p_{ji,1} + \frac{E_{bi,2}\tau_{si,1}}{E_{bi,1}\tau_{si,2}} \left(1 - p_{ji,1}\right) \right), \qquad (4)$$

here $p_{ji,1}$ – is the probability of a total attenuation being $L > L_2$, L_2 – the total attenuation corresponding to the transition from one modulation method to another, L_k – the number of BS radio transmitter channels, and $\tau_{si,1}$ and $\tau_{si,2}$ – the duration of one bit in QPSK and 16-QAM modulations respectively, $E_{bi,1}$ and $E_{bi,2}$ – is the bit energy in QPSK and 16-QAM modulations.

In order to adjust the power of the BS radio transmitter or to change the modulation method, the parameters of the pilot signal to be measured changed in parameters as it passed through a turbulent environment such as a communication channel, as well as the BS radio receiver amplifier and demodulator were studied.

The effect of the pilot signal power or the signal/interference ratio measurement accuracy on the adaptive modification of the modulation method was studied. For this purpose, the effect of the number of positions of QAM signals on the background of fluctuation noise and under the influence of broadband interference on the error probability at different values of the energy parameter was calculated.

It has been shown that if the modulation method is adapted to the LMDS system, then the modulation mode will switch from one to another - more noise immunitive - at relatively small changes in the signal/interference ratio when the allowable value of the error probability is large. This means that even small measurement errors of signal/interference ratio or signal power will cause the modulation mode to change.

In the fourth chapter of the dissertation, scientific and technical problems of MMDS, LMDS and MVDS type cellular radio access networks application have been studied. In this chapter entitled “Experimental substantiation of the accuracy of the obtained results. "The main scientific and technical problems of the application of multi-channel TV in Baku and the Absheron Peninsula", a mathematical expression was derived to calculate the required signal power at the input of the radio receiver in order to determine the power of the main radio transmitter.

In the previous chapters of the dissertation, the characteristics of communication in the considered frequency band, the issues of reducing interferences arising in the formation, transmission, processing of broadband signals and interferences related to the network topology were studied. However, the construction of the network as a scientific and technical problem must be carried out taking into account different factors for each area. In addition to the area planning of BS in the network under consideration, the power of their radio transmitters should be selected. The power of the main station was determined for the construction of MMDS, LMDS or MVDS type cellular network in Baku and Absheron peninsula, the equivalent height of the antenna was calculated taking into account the profile of the terrain, the electric height of the antenna and the height of the tower above sea level. With the help of a computer program, a diagram of its coverage area was drawn (Fig. 3). It is clear from the obtained diagram that there are areas in Zykh and Garachukhur areas where it is not possible to receive the signal of this system at all (white areas shown on the map). It is not possible to eliminate the "gap" area by increasing the power of the main transmitter. The relief of the peninsula is such that it will not be possible to cover a large area with a small number of radio transmitters. On the other hand, the advantages of covering the area with a large number low-power BS are also known. The most important of these is to ensure environmental safety and communication independent of any BS. Therefore, the use of an appropriate booster is proposed, and the principles of selection of its location and equipment are substantiated (Fig. 4).

When interference is affected in the service area, the power of the transmitter is calculated according to the required value of the signal/interference ratio. In this case, it is assumed that the levels of both the useful signal and the interference signals fluctuate according to the logarithmic-normal model during spatial propagation, and a mathematical expression is derived for determine the signal/interference ratio by power:

$$w = \frac{P_s R_m^{k_m}}{P_m R_s^{k_s}} 10^{0,1(x_s - x_m)}, \tag{5}$$

here k_s and k_m – are the coefficients characterizing the attenuation rates of the signal and interference depending on the distance, R_s – is the distance from the receiver to the station of the useful signal, R_m – is the distance from the receiver to the interfering station, P_s and P_m – respectively are the powers of the signal and interference, x_s and x_m – are random quantities that determine the fluctuation levels of the useful signal and of the interferences respectively.

The mathematical expression for the signal/interference ratio is derived both for a single interference and for numerous interferences. It is clear from here that the power of the BS radio transmitter also depends on the power of the interferences in the communication channel. However, the total power of the interferences at the input of the radio receiver cannot be found as the sum of the powers of the individual interferences. How the total power is calculated depends on the type of channel. For example, the Fenton method can be used to power

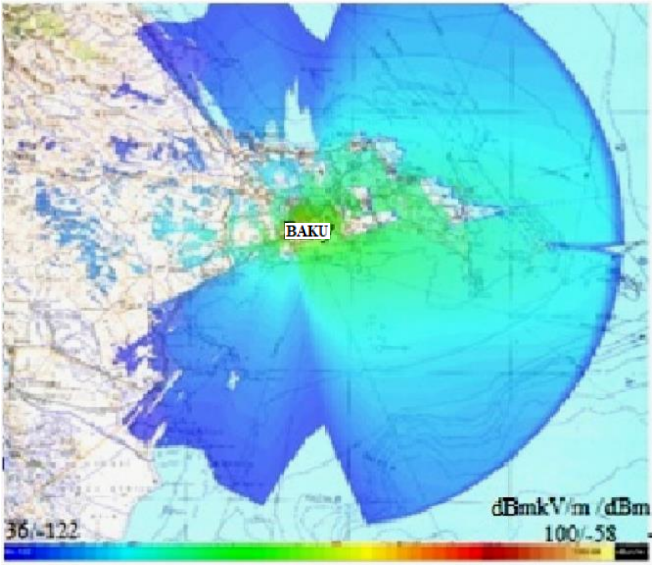

Fig.3. Service area of the main radio transmitter

Fig. 4. Location of the main radio transmitter and the booster in the territory of the Absheron Peninsula

summation in the Gaussian channel. According to this method, the sum of several random processes distributed by the logarithmic-normal model again obeys the logarithmic-normal model, but the new statistical parameters of this random process must be calculated by the Fenton method.

In this case, when calculating the signal/ interference ratio at the receiving point, it is sufficient to write the total power of the interferences calculated by the Fenton method instead of the power of the interference in expression (5).

Taking into account that the power transmitters of BS in a homogeneous network are equal, the dependence w = f (R_m/R_s) was derived for a homogeneous network using formula (5) (Figure 5). It is clear from the graphs that the signal/interference ratio is affected by both the distance from the receiving point to the signal and interference sources, the signal and interference attenuation velocities depending on the distance, and the fluctuation level $\gamma_1 = x_s - x_m$. As the value of the γ_1 parameter increases, so does the value of the signal/interference ratio. The signal/interference ratio, in turn, depends on the distance of the interference and its rate of attenuation.

The existence of an analytical relationship between the three efficiencies of communication systems - information, energy and spectral efficiency, both between themselves and the capacity of the channel, is substantiated in the first chapter of the dissertation.

If we use the known analytical expression between the signal power and the energy parameter, we can see that these two parameters are equivalent to each other when the other parameters do not change. When three modulation methods such as QPSK, 16-QAM and 64-QAM are applied and the rate of the converted code is 5/6, we calculate these parameters and write them in Table 3, where $\beta_t = P/N$ – is the required signal/noise ratio, β_{tn} – is its normalized value, ε_{efn} – is normalized value of the spectral efficiency, i_n – is normalized value of information efficiency. In order to determine the increase in parameters, the values of the parameters in Table 3 were normalized to the minimum value.

There has been an β_{tn} time increase capacity in considered broadcast channel. When the capacity of a discrete channel with interference is greater than the transmission speed, encoding can be used to transmit information on that channel with the possibility of very small errors.

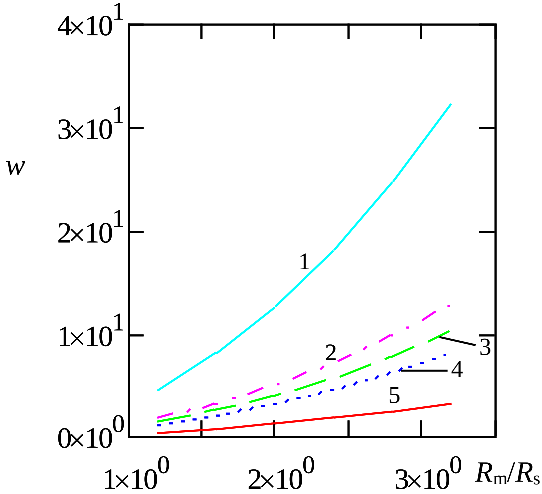

Fig. 5. $w = f(R_m/R_s)$ dependence:
$k_s=k_m=2$; 1. $\gamma_1 = -5$; 2. $\gamma_1 = -1$;
3. $\gamma_1 = 0$; 4. $\gamma_1 = 1$; 5. $\gamma_1 = 5$.

We can calculate the required capacity in QPSK modulation by the expression $C_n = \Delta f \log_2(1+\beta_{tn} P_1 / N)$, here P_1 / N – is the signal/noise ratio for the QPSK modulation. When for QPSK modulation $p_s = 1 \cdot 10^{-5}$ then $\beta_{tn} = 1$. For other modulation methods and other values of p_s in $P/N >> 1$ we can approximate the required capacity with the same formula. For example, and for $p_s = 1 \cdot 10^{-5}$ and 16-QAM we find: $C_{n2} = 1 + \frac{\log_2 \beta_{tn2}}{C_{n1}} = 1 + \frac{0{,}54}{C_{n1}}$. In the same way, we calculate the normalized values of capacity and information efficiency in 64-QAM modulation and write them in Table 3.

The table shows that increasing the energy parameter leads to an increase in capacity. It is clear that with the increase in the number of

Table 3

Eefficiency and capacity in the multi-channel TV systems

	β_{tn}		ε_{efn}		C_n		i_n	
	p_s=10^{-5}	p_s=10^{-7}	p_s=10^{-5}	p_s=10^{-7}	p_s=10^{-5}	p_s=10^{-7}	p_s=10^{-5}	p_s=10^{-7}
QPSK	1	1,2	1	1	C_{n1}	$1+\frac{0,26}{C_{n1}}$	$1/C_{n1}$	$\frac{C_{n1}}{0,26+C_{n1}}$
16-QAM	1,46	1,59	1,99	1,99	$1+\frac{0,54}{C_{n1}}$	$1+\frac{0,67}{C_{n1}}$	$\frac{1,99C_{n1}}{0,54+C_{n1}}$	$\frac{1,99C_{n1}}{0,67+C_{n1}}$
64-QAM	1,85	1,99	2,99	2,99	$1+\frac{0,89}{C_{n1}}$	$1+\frac{0,99}{C_{n1}}$	$\frac{2,99C_{n1}}{0,89+C_{n1}}$	$\frac{2,99C_{n1}}{0,99+C_{n1}}$

positions in the QAM modulation, the transmission speed and, consequently, the spectral efficiency increases. It is clear from the table that in both cases, an increase in the P_1/N ratio leads to an increase in the required capacity and, consequently, information efficiency, but in $p_s = 1\cdot 10^{-7}$ this increase is greater.

Communication is established between the main BS and the booster station located in Zykh settlement. This additional track is required to detect attenuation. Our purpose is not to calculate the numerical value of the signal power at the receiving point (i.e. the attenuation in the track). Accurate calculation of the attenuation that occurs during the propagation of signals in space is a difficult. When the expressions for calculating the attenuation and type of the track are known, these attenuations can be calculated with certain accuracy. However, these models and expressions are different, and the selection of the appropriate one requires some research.

In fact, this track is a mixed track, part of which passes through the sea and part through land (see Figure 5). The sea track causes small attenuation, the land track – large attenuation, and the mixed track – intermittent attenuation. Take into consideration the small size of the land part, we can classify this track as a sea track group. In this case, a two-beam model is used. A sea track is a track that runs completely over the sea. Such tracks are divided into two parts: hot sea tracks and cold sea tracks. The first type of tracks includes seas, oceans and other large water basins below the 23.50 latitude. The second type of tracks includes seas, oceans and large water basins above 23.50 latitude. Therefore, the considered track, i.e. the Caspian Sea, belongs to the hot sea track. Such tracks have a positive effect on the propagation of radio waves and create great refraction. In general, the sea surface acts as a wave guard for the propagation of waves. Based on these considerations, appropriate expressions were selected to calculate the attenuation that occurs during the propagation of waves on the main radio-buster line.

Although the research confirmed that it is advisable to choose MMDS or LMDS type systems in the cable TV distribution network, it also showed that it is important to take various technical measures during the construction of the network. Thus, the upper limit on the choice of BS radio transmitter power is aimed at reducing interferences related to network topology.

The **main scientific results** of the dissertation are included in the results. The most important of them are:

- sometimes, due to their known advantages, the "last mile" communication is completed using a broadband cellular radio access network. Although there are different variants of this type of systems, common features such as broadband signals, building on the cellular principle, ultra high-frequency operation, highly integrated services, and the use of certain multiparameter modulation methods suggest that common problems will be common;

- the resulting nonlinear distortions are mainly the result of physical processes occurring in powerful transistors, and therefore it is impossible to seriously influence the sources of nonlinear distortions. However, these distortions can be reduced by using additional correction schemes and by correctly selecting the amplifier mode and the levels of the sub-carriers of the multi-channel TV broadcast signal;

– the statistical parameters of a multi-channel TV broadcast signal differ from the corresponding statistical parameters of the channel signal. The value of the dispersion of the total signal of a multi-channel TV broadcast increases in proportion to the number of channels;

- strict requirements for nonlinear distortions are set here, as amplitude-phase modulation is applied in multi-channel TV broadcasting systems. When the amplitude characteristic of an amplifier is approximated by a polynomial, the power of the AM-AM transition interferences depends on the power of the input signal, the change rate of the correlation function of the input random process, and the characteristics of the nonlinear element;

- when looking for a compromise between the power of the BS radio transmitter and the modulation method in the direct channel of the LMDS type network, it is expedient to select and adapt the modulation method according to the measured value of the signal power or signal/interference ratio to ensure data transmission accuracy;

- in the LMDS system, the power or signal/interference ratio measurement system is more sensitive to measurement errors if there is a soft requirement for an allowable value of error probability when adapting the signal modulation method in the BS radio transmitter. Thus, when the allowable value of the error probability is $p_S = 0.16$ the modulation mode changes with a 1.6 times increase in $h^2_{b\Sigma}$ and when $p_S = 0.08$, this change occurs with a 2.7 times increase in $h^2_{b\Sigma}$;

– in order to build a broadband wireless radio access network in Baku and the Absheron Peninsula, it is advisable to significantly reduce the power of the main radio transmitter MMDS located in the Baku TV Tower and use a directional antenna and a booster located in a selected area to the right of Baku Bay.

In the **appendix** the amplitude distribution model of the pilot signal at the input of the signal/interference ratio measuring circuit of the BS radio receiver of the LMDS system is determined. This distribution model derived from the fact that the initial stage of the demodulator is a narrow-band filter.

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