Contemporary Engineering Sciences, Vol. 9, 2016, no. 10, 473 - 485
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2016.629

Adaptive Regulation of Radiated Power Radio Transmitting Devices in Modern Cellular Network Depending on Climatic Conditions

Mazin Al Hadidi

Computer Engineering Department. Faculty of Engineering Technology
Al-Balqa' Applied University, Jordan

Jamil S. Al-Azzeh

Computer Engineering Department. Faculty of Engineering Technology
Al-Balqa' Applied University, Jordan

R. Odarchenko

Academic Department of Telecommunication Systems
National Aviation University, Kyiv, Ukraine

Sergiy Gnatyuk

Academic Department of IT-Security
National Aviation University, Kyiv Ukraine

A. Abakumova

Academic Department of Telecommunication Systems
National Aviation University, Kyiv, Ukraine

Abstract

The paper presents a detailed analysis of the environmental conditions that can affect the signal/noise ratio at the input of receivers in modern cellular networks. We conducted computer simulations quantities of signal attenuation in adverse climatic conditions. Based on this analysis, we developed a method of regulation radiated power radio transmitting devices depending on climatic conditions and showed the block diagram of a system, which enables to implement the proposed method. Also in this paper, first proposed the concept of building a sensor network for collecting weather data.

Keywords: cellular communication network, base station, mobile station, the radio signal strength, power control, climatic conditions, signal attenuation, hydrometeors, sensor network

Introduction

The last decades characterized by rapid introduction of cellular mobile communication systems intended for transferring telephone messages and digital data to mobile subscribers [19]. In the operation of such networks may be problems with the transmission of data related to the level of signal strength on the receiving side. Since the channels of radio communication always affect by various types of fading, which is a major obstacle to the efficient and reliable transmission of radio signals, it is necessary to take into account the ongoing impact of these different types of fading that can be caused by hydrometeors, attenuation in atmospheric gases etc. One of the effective methods to combat fading, in terms of automatic control theory is a method for providing feedback [20] for regulation radiated power radio transmitters. The essence of this method is that the information about the state of radio direct path and corresponding change in the parameters of the signal at the input of the radio transmission is transmitted by channel feedback, i.e. from radio to radio. Direct channel radio communication with return channel of radio control (which uses the method of feedback) is a dynamic closed system of automatic control [21].

Analysis of research and publications

Such systems are described in a number of national researches, but their analysis and synthesis of automatic control theory point of view in the known literature is missing [4]. Known ways of organizing cellular networks [10-12] and ways of regulation radiated power of base stations (BS) and mobile stations (MS) [2, 6, 7, 13, 14] involve changing the transmitter power BS and MS, depending on the measured level of the received signal. Then the decision is accepted to increase or decrease radiated power radio transmitters BS and MS to the level required for efficient communication. These algorithms have been successfully used in cellular networks of the second, third and fourth generations [3, 17-18]. Many beam nature propagation of radio waves strongly influences on the communication quality. That is why with negligible change location MS signal strength may be significantly reduced, even breaking the link may occur. Therefore, in addition to power control used handover algorithms (transfer calls from one base station to another) [9].

Problem formulation

The implementation of the algorithms happens according to internal procedures specific technologies of construction cellular networks. An important role in a process of power regulation radio transmitting devices play receiver sensitivity, power transmitters, the distance between the transmitter and receiver, the number and nature of obstacles, terrain of the underlying surface. Thus, the communication quality depends on the signal/noise ratio at the input of receivers, which decreases due to the signal distribution distance, absorption of atmospheric gases, hydrometeors etc. Existing algorithms of transmitters' power regulation of radio transmitting devices make it possible to increase the radiated power to the level necessary for a quality communication session by measuring the level of signal strength. However, it may happen that the signal level can rapidly fall below acceptable level, leading to breakage of wireless communication (for example, in heavy rain, fog, snow, etc.). In this case, it will be impossible to exchange control information between the transmitting and receiving devices. In cellular networks 4th generation also possible to use the automatic shift data rates algorithms depending on the actual measured signal/noise ratio at the receiving side. However, in this case at falling of signal strength level due to climatic conditions (for example, temperature increase, absorption of atmospheric gases, hydro meteors, fog) can incur significant loss by the data rate, which cannot satisfy end users of telecommunication resources cellular networks.

Thus, the main task, which should solve the proposed method, is adaptive of power regulation transmitting devices cellular networks (BS and MS), depending on climatic conditions, which should provide constant high communication quality for various climatic conditions.

The main part of research

Set tasks are solved by the fact that capacity management should be carried out depending on the climatic conditions. This may provide an opportunity to support the quality of communication at the appropriate level, even under difficult climatic conditions.

Thus was developed a method of power regulation radio transmitting devices cellular networks. In the proposed method required to use telemetry sensors that need to connect to the BS. They collect information about deviations from normal climatic conditions (ambient temperature: +20 +/-5 deg. ^{0}C; relative humidity 60 +/-15%; pressure: from 84 kPa to 107 kPa). Particular, determining ambient temperature, humidity, characteristics and amount of precipitations (rain, snow and their intensity), the presence of fog (its characteristics). First, be sure to set the initial level of radiated power radio transmitters P_{tr0} (in dB or dBm) for certain initial conditions (for example, temperature 20 deg. ^{0}C, relative humidity 60 +/- 15%, in the absence of hydrometeors). This level of radiation power is taken as a reference against which the level change of the power transmission devices on ΔR value happen, depending on climatic conditions. Measured telemetric information stored in a specialized telemetry data that can be stored on special servers. After recording, information processed by specialized software in the computer center of the base station. With specialized software, decision is taken about the need to increase or decrease radiated power radio transmitting devices.

In this paper, propose that amount of level change power radio transmitting devices cellular networks ΔR includes power compensation of attenuation from hydrometeors ΔR_{hm}, to compensation of radio signal attenuation in atmospheric gases ΔR_{ag}, to temperature compensation ΔR_{tc}, to compensation of attenuation in fog ΔR_{fog}.

First, using telemetry sensors necessary to detect the presence of hydrometeors, fog. If they are present, the level of linear compensation is calculated using the specialized software:

- *for fog [9]:*

$$g_C = K_l M \quad \text{dB/km}, \tag{1}$$

g_c :linear weakening (dB/km) in the conditions of cloudiness; K_l : coefficient of linear weakening ((dB/km)/(g/m^3)); M : the density of liquid water in clouds or fog (g/m^3).

To calculate the coefficient of linear weakening K_l for frequencies up to 1000 GHz using a mathematical model:

$$K_l = \frac{0{,}819f}{\varepsilon''(1 + \eta^2)} \quad (\text{dB/km})(\text{g/m}^3), \tag{2}$$

where f – frequency (GHz) and

$$\eta = \frac{2+\varepsilon'}{\varepsilon''}. \tag{3}$$

The complex dielectric permittivity of water is given by the expressions:

$$\varepsilon''(f) = \frac{f(\varepsilon_0 - \varepsilon_1)}{f_p\left[1+(f/f_p)^2\right]} + \frac{f(\varepsilon_1 - \varepsilon_2)}{f_s\left[1+(f/f_s)^2\right]}, \tag{4}$$

$$\varepsilon'(f) = \frac{\varepsilon_0 - \varepsilon_1}{\left[1+(f/f_p)^2\right]} + \frac{\varepsilon_1 - \varepsilon_2}{\left[1+(f/f_s)^2\right]} + \varepsilon_2, \tag{5}$$

where:

$$\varepsilon_0 = 77{,}6 + 103{,}3\,(\theta - 1); \tag{6}$$

$$\varepsilon_1 = 5{,}48; \tag{7}$$

$$\varepsilon_2 = 3{,}51; \tag{8}$$

$$\theta = 300/T, \tag{9}$$

and T – temperature (K).

The main and secondary relaxation frequencies:

$$f_p = 20{,}09 - 142\ (\theta - 1) + 294\ (\theta - 1)^2 \text{GHz}, \tag{10}$$

$$f_s = 590 - 1\ 500\ (\theta - 1)\ \text{GHz}. \tag{11}$$

Figure 1 shows the linear dependence of the attenuation caused by drops of water at various temperatures depending on the frequency [16]. The weakening significantly felt at frequencies above 5 GHz.

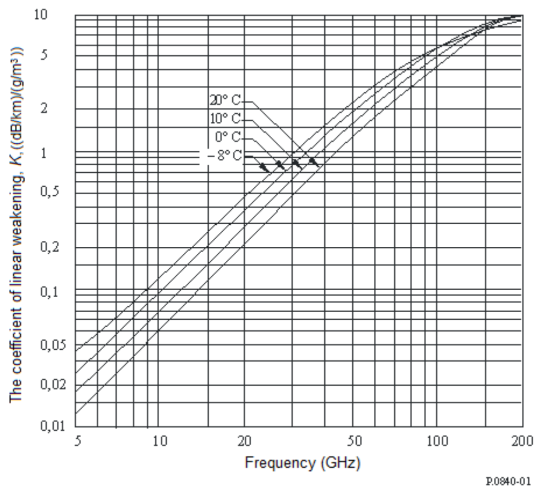


Fig. 1. Linear dependence of the attenuation caused by drops of water at various temperatures depending on the frequency

Thus, signals, which transmitted in the networks of WiMAX, may incur considerable weakening and radio signals exchanged between base stations using radio relay transmission systems.

- *for hydrometeors [8]:*

$$\gamma_R = kR^{\alpha}. \tag{12}$$

The coefficients k and α may alternatively define a function of frequency from the following equations:

$$\log k = \sum_{j=1}^{3} \left(a_j \exp\left[-\left(\frac{\log f - b_j}{c_j} \right)^2 \right] \right) + m_k \log f + c_k \tag{13}$$

$$\alpha = \sum_{i=1}^{4} \left(a_i \exp\left[-\left(\frac{\log f - b_i}{c_i} \right)^2 \right] \right) + m_\alpha \log f + c_\alpha\ , \tag{14}$$

where f : frequency (GHz), k : k_H or k_V, α : α_H or α_V.

Figure 2 illustrates linear dependence of the attenuation in hydrometeors depending on the radio signal frequency for various values of the intensity of precipitation.

Then we can determine the full level of compensation capacity:

- for fog:

$$\Delta P_{fog} = g_c \cdot l_{ef}, \tag{15}$$

- *for hydrometeors:*

$$\Delta P_{hm} = \gamma_R \cdot l_{e\phi} \tag{16}$$

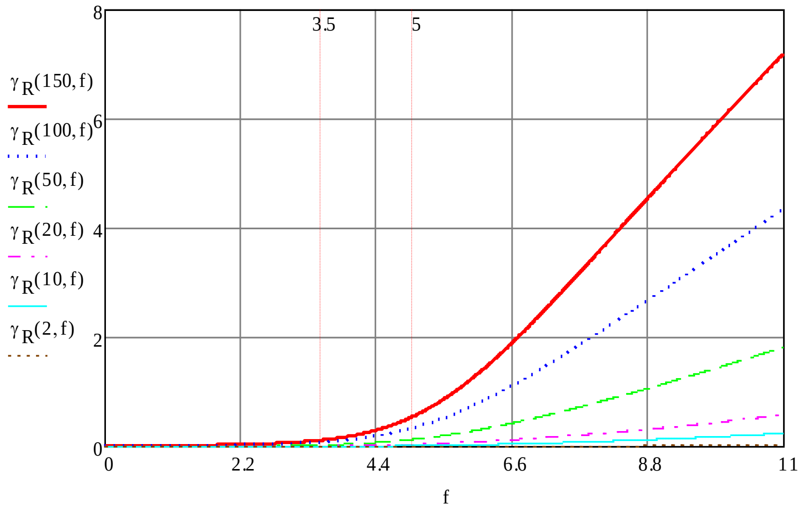


Fig. 2. Linear dependence of the attenuation in hydrometeors depending on the radio signal frequency

In (15) and (16) l_{ef} - is the effective length of the track signal propagation. For cellular networks, the value l_{ef} is theoretically calculated cell radius, which determine while planning a network. If hydrometeors or fog is absent, the level of compensation is equal to 0, namely $\Delta P_{fog} = 0$ and/or $\Delta P_{hm} = 0$. Then use the specialized software to calculate the attenuation of radio waves caused by molecular absorption them in the atmosphere gases at the range of radio links which is the equivalent of:

$$\Delta P_{ag} = V_g = -\gamma_{ag} R_0, \text{ dB}, \tag{17}$$

where γ_{ag}, dB/km, - is a linear attenuation of radio waves in the atmosphere gases considering temperature correction (18).

$$\gamma_{ag} = [1 - 0{,}01(t - 15)]\gamma_0 + [1 - 0{,}006(t - 15)]\gamma_{H2O}, \tag{18}$$

where γ_O, dB/km, – linear attenuation of radio waves in oxygen; γ_{H2O}, dB/km, – linear attenuation of radio waves in the water vapor of the atmosphere; t – air temperature, ^{0}C.

Simplified expression for the linear attenuation in oxygen of the atmosphere, dB/km, for the range of frequencies less than 57 GHz at normal atmospheric pressure and a temperature of 15 °C is the following:

$$\gamma_O = \left(7{,}19\cdot 10^{-3} + \frac{6{,}09}{f^2 + 0{,}227} + \frac{4{,}81}{(f-57)^2 + 1{,}5}\right) f^2 \cdot 10^{-3}, \quad (19)$$

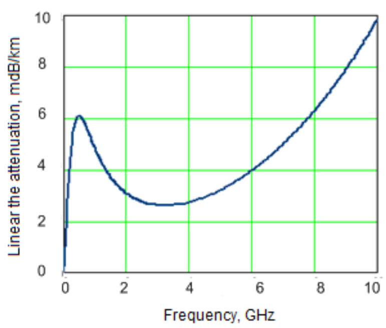
where f – frequency, GHz.

To estimate γ_{H2O}, at the Earth's surface with temperature t = 15 °C for frequencies up to 350 GHz using the ratio:

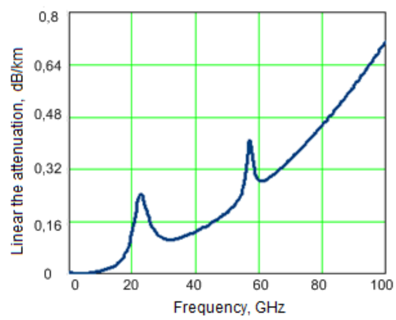
$$\gamma_{H2O} = \left(0{,}05 + 0{,}0021\rho + \frac{3{,}6}{(f-22{,}2)^2 + 8{,}5} + \frac{10{,}6}{(f-183{,}3)^2 + 9} + \frac{8{,}9}{(f-325{,}4)^2 + 26{,}3}\right) f^2 \rho \cdot 10^{-4}, \quad (20)$$

where ρ – absolute air humidity, g/m^3; f – frequency, GHz.

Figure 3 illustrates the linear dependence of the attenuation in the atmospheric gases from radio frequency range from 0 to 10 GHz (Fig. 3 (a)) and from 0 to 100 GHz (Fig. 3 (b)).



(a)



(b)

Fig. 3. The linear dependence of the attenuation in the atmospheric gases from radio frequency range from 0 to 10 GHz (a) and from 0 to 100 GHz (b)

In (17) $R_0 = l_{ef}$. Then use the specialized software, value of temperature compensation calculated by the formula [5]:

$$\Delta P_{tc} = 10\cdot lg(kTR) \text{ (dB)}, \quad (21)$$

where k =1,38·10^{-23} J/k – Boltzmann constant; T – absolute temperature (K); R – speed data transmission in a cellular network (bit/s).

Then determine the change of power transmitting devices in cellular networks ΔP:

$$\Delta P = \Delta P_{tc} + \Delta P_{fog} + \Delta P_{\text{hm}} + \Delta P_{ag}. \quad (22)$$

Thus in (22) terms ΔP_{fog}, ΔP_{hm}, $\Delta P_{ag} \geq 0$; ΔP_{tc} can be added as well as negative. Therefore, by the last parameter radiated power can both increase and decrease. After the calculations ΔP decide to change transmitters' power BS in cellular networks exactly on the value ΔP. Later BS form control message, which transmit recommendations on changing transmitters' power MS on the value ΔP.

Block diagram of the developed system of regulation radiated power radio transmitting devices of cellular networks, depending on climate conditions shown in Fig. 4. The proposed way of collecting telemetry data to the proposed regulation system is to use specially built sensor network for these purposes, which deploying is dedicated to [15, 16]. A wireless sensor network designed for these purposes is a self-organizing network, which consists of many wireless sensor nodes distributed in space and intended to monitor the characteristics of the environment. The space that is covered with sensor networks - sensor field that is designed to collect meteorological data.

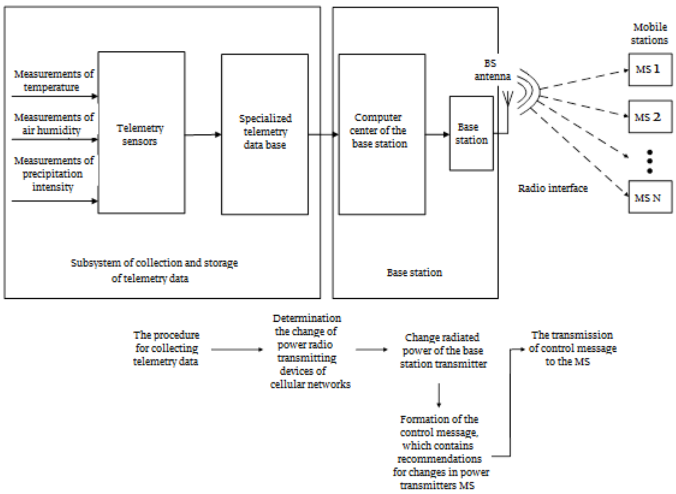


Fig. 4. Block diagram of the regulation system radiated power radio transmitting devices of cellular networks, depending on climate conditions

Actually wireless sensor nodes are tiny devices with a limited set of resources: battery charge, memory, computing capabilities and others. It is suggested that such device has the following block diagram shown in Fig. 5 to achieve the purposes of collecting meteorological data. It is an advanced node structure of sensor network, considered in [22].

Structurally, each node should consist of compulsory sensors (temperature, hydrometeors, humidity). In addition, we can connect optional sensors (for example, to measure seismic activity, intensity of the electromagnetic field, etc.). All sensors are connected to the signal generator via standard interfaces. Further collected information subjected to multiplexing and amplification, and then the analog signal is formed into digital one with the help of ADC (analog-to-digital converter). The digital signal from the output of the ADC is fed to the input of the microcontroller, which will transmit the processed information in parallel saving in storage for counters' data logging and to the input of the HF (high frequency) transceiver, which via HF antenna device radio signal will be transmitted to the next node.

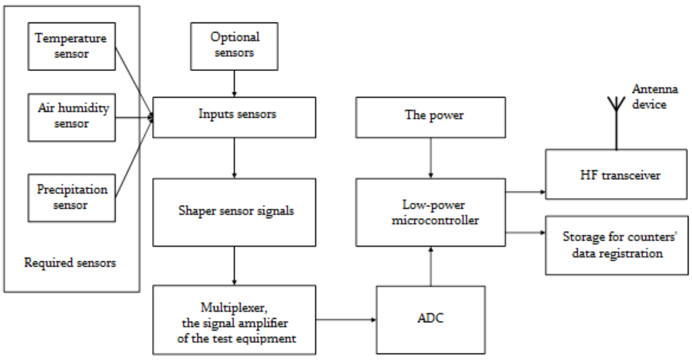


Fig. 5. Block diagram node sensor network for collecting weather data

Technology for organizing sensor network can be developed based on many existing standards. One of them, for example, is a technology ZigBee (IEEE 802.15.4). ZigBee technology parameters listed in Table 1.

Table 1
ZigBee technology parameters

Parameter	Value data
Type of network topology	Full mesh-network
The distance between nodes, m	70
The speed of data exchange, kbit/s	250
The maximum number of nodes	65520
Operating frequency range, GHz	2,4 (16 channels)
Energy Conservation Opportunities	Incomplete (go to standby allowed only to end nodes)
Complexity	High (128 kbps flash memory)
Cost	Low
Reliability	Good
Sustainability	Yes
Standardization	Yes
Cooperation with other devices	Yes

The Table 2 shows the basic specifications for ZigBee-modems of Telegesis Company.

Table 2
Specifications for ZigBee-modems of Telegesis Company

Model	Channel specifications		Hardware resources		Current consump-tion, mA	Temperature range
	Max. transmitter power, dBm	Receiver sensitivity, dBm	The number of digital outputs	Analog inputs		
ETRX1	0	-94	8	2	15	-40…+85
ETRX2	5	-97	12	2	1	-40…+85
ETRX2-PA	20	-97	12	2	2	-40…+85

Combining these units into a single network will provide the possibility of unified picture of events and processes within the field of touch. Wireless sensor nodes will collect information and pass it further for processing and analysis. Approximate sensor network structure for solving the tasks looks as follows (Fig. 6).

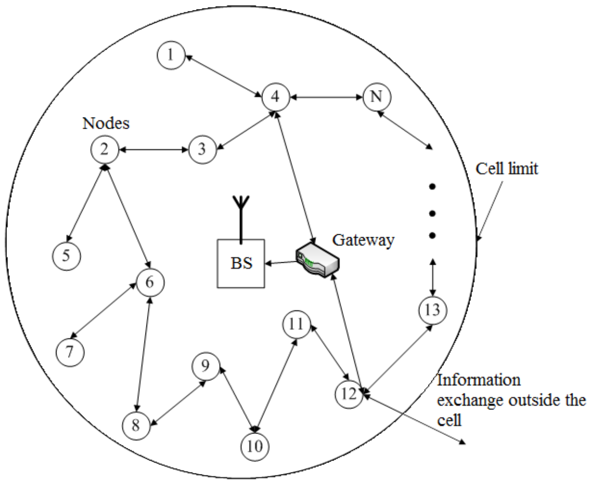


Fig. 6. Structure of the sensor network within a single cell

The basis of sensor network shown in Fig. 6, constitute many sensor nodes that can communicate with each other. Sensors will be placed inside each cell. Their number should be varied depending on the nature of the terrain, the size of cells and so on. Each node can perform various functions (can act as a coordinator of the network, router or be a simple touch hub). Obligatory element of the proposed structure is a sensor network gateway (can be more than one gateway in one network) through which will transfer the collected meteorological information to the base station. The wireless sensor networks can be built on the same type or different types of sensor nodes. However, the construction is proposed exactly on diverse nodes, because the construction of a network on the similar (but more efficient units) will be much more expensive, though it can perform more tasks entrusted to it. In a heterogeneous network, various sensor nodes can have different energy intensity, measured set of parameters, computing capabilities. Sensor nodes can be randomly located on the territories of the different density filling territory or placed in accordance with the plan of the network construction. Naturally, algorithms for data distribution between sensor nodes in the first and the second case or objects located in it will be much different. Data exchange can occur by alternatively chosen a different route, as shown in Fig. 6. At the same sensors that are on the verge of cells may hold the nodes exchange information with the neighboring cells. Since the sensor network contains a large number of sensor nodes and the most important feature of sensor network in general must be network performance of its functions even in case of failure of some maximum possible number of sensor nodes. It is necessary to create such control algorithms of sensor nodes to minimize energy consumption and provide load redistribution between nodes. The amount of information packets transmitted, received and processed by each sensor node should be such that energy costs were minimized.

Another problem in the construction of wireless sensor networks is that the distance at which the sensor node transmits information may be significantly less than in the traditional radio systems. Therefore, transmitter power should be small (it contributes to the low power) and wireless sensor network architecture should be the distribution network of intellectual resources. Such networks related to self-organizing. Common examples of such networks are networks MANET (Mobile Ad Hoc Network) [1]. Thus, the proposed structure of the sensor network will allow collecting detailed information on the current climate, to build their weather maps within cells using specialized software and make decisions about the need to regulate radiated power radio transmitters within individual cells, thereby avoiding communication gaps. In addition, the installation of additional optional sensors to the sensor nodes allow operators to use sensor network not only for its main purpose, but also for other research or commercial purposes. Among them are the following [15]: 1) Security systems – control perimeters, the definition of invasion, remote monitoring; monitoring of staff, protection of valuable works of art, home security systems, fire alarm systems. 2) Monitoring and control environment system (humidity, temperature, composition of the air/soil/water, pressure, magnetic background) monitoring environmental pollution, migration of animals and insects. 3) Electricity system – energy management; control air-conditioning, ventilation, heating, lighting; repeaters counters for gas, water, electricity. 4) Emergencies – warning of natural disasters: forest fires, landslides, etc.; rescue people in emergencies.

Therefore, operator of cellular networks will not only cover the overhead costs of deployment supporting sensor network, but also to make parallel delivery of its lease to certain organizations or individuals. Therefore, this solution to the problem of collecting telemetry data is the most appropriate in the future, although the first phase of implementation will be required capital investments. In addition, sensor networks can be used in parallel with technology to request meteorological information from specialized meteorological data servers. This will make it possible to conduct hot backup and prevent the emergence of critical situations related to the customer service's deterioration of the quality, or with the break sessions.

Conclusions

Thus during the research it was developed a regulation system of radiated power radio transmitting devices of cellular networks depending on climatic conditions. Putting block to determine the climatic conditions of the environment and correcting transmitters' power BS and MS to existing ways of regulating transmitters' power MS and BS in cellular networks allows maintaining a constant data transmission speed on the cellular network, while providing acceptable probability of bit errors and maintaining the necessary signal/noise ratio at the receiving side. It allows cellular networks' users to receive high quality communication, while not increasing the negative impact of electromagnetic radiation from base stations because the increased capacity compensates only reduction for signal strength under the influence of climatic conditions. In further research is planned to develop the structure of the sensor network, which will collect data on the external climatic conditions within individual cell network and transmit them to the base station. Also proposed a new concept sensor network that will collect data on the external meteorological conditions within individual cell network and transmit them to the base station. In addition, this sensor network can be used in parallel to the implementation of other commercial projects, making it more attractive to mobile operators.

References

[1] A. Footage, E. Curly, A. Curly, LTE and wireless sensor networks, Mobile telecommunications, 9-10 (2012), 38-42.

[2] AN-1433 Base Station Closed-Loop RF Power Control with LMV232 Crest Factor Invariant Detector, Texas Instruments, Application Report, January 2006.

[3] M.P. Boiko, Cellular systems: Lections, Odesa: ONAZ, 2004, 76.

[4] O.M. Franzevich *Mathematical Model for Radio Channel with Adaptive Manegement*: Diss., candidate m. sciences, Kyiv, 2005, 140.

[5] G.F. Konahovich, M.G. Lutskiy, R.S. Odarchenko, IEEE 802.11g Standard access point range determination method, Information Security, Kyiv, 17 (2010), 269-277.

[6] M. Chiang, P. Hande, T. Lan, C. Wei Tan, Power Control in Wireless Cellular

Networks, *Foundations and Trends in Networking*, **2** (2008), 381-533. http://dx.doi.org/10.1561/1300000009

[7] Patent number US 6,765,897 B2, the IPC H04B7 / 216, 2004.

[8] Recommendation ITU-R P.838-2 specific attenuation model for rain for use in prediction methods, 2003.

[9] Recommendation ITU-R P.840-5 Attenuation due to clouds and fog, 02/2012.

[10] RF patent number 2269872, IPC H04B7 / 26 (2006.01), 2004.

[11] RF patent number 2248098, H04B7 / 26 IPC 2002.

[12] RF Patent number 2114508, IPC 7/005 H04V 1994.

[13] RF Patent number 2212119, IPC H04Q7 / 38, H04B7 / 26, 2003.

[14] RF Patent number 2387075, IPC H04B1 / 00 (2006.01), 2010.

[15] R.M. Alguliev, T. Fataliyev, B.S. Agayev, T.S. Aliyev, Sensor networks: state, solutions and prospects, Telecommunications, Moscow, Publishing House, Science and Technology, (2007), 27-33.

[16] A. Dmitriev, E.V. Efremova, A.V. Kletsov, L.V. Kuzmin, A.M. Laktyushkin, V.Y. Yurkin, The UWB wireless communication and sensor networks, *Technology and Electronics*, **53** (2008), no. 10, 1278-1289.

[17] V.M. Vishnevsky, S.L. Taylor, I.V. Shakhnovich, Encyclopedia WiMAX: Path to 4G, Moscow, Technosphere, 2009, 472.

[18] V.O. Tikhvinskiy, S.V. Terentyev, A.B. Yurchuk, LTE Mobile networks: technology and architecture, Moscow, Eco-Trendz, 2010, 284.

[19] V.P. Ipatov, V.K. Orlov, I.M. Samoilov, V.N. Smirnov. Mobile communication systems: A manual for schools, Moscow: Hotline Telecom, 2003, 272.

[20] G.F. Zaitsev, G.N. Arsenev, V.G. Krivutsa, V.L. Bulgach, Radioautomatics, Vol. 1, Kyiv, SUICT, 2004, 523.

[21] G.F. Zaitsev, V.K. Steklov, O.I. Britsky, Automate management theory, Kyiv, Tehnika, 2002, 688.

Received: February 17, 2016; Published: May 15, 2016