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MITRIS SYSTEM WITH COMBINED QUADRATURE-AMPLITUDE AND FREQUENCY MODULATION

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The telecast and Internet distribution system, which use combined two-level modulation and intended for digital information transfer in frequency band 11,7—12,5 GHz was created on a base of the existing microwave integrated telecommunication system MITRIS. In comparison with telecommunication system using 64-QAM modulation with one carrier, new system has significantly better power engineering, less hard requirements to the frequency stability, to the phase noise level and to the linearity of the amplitude-frequency and phase-frequency characteristics of communication channel.

Introduction

Recently there has been a worldwide change of analog TV to digital broadcasting. During 1996—1997 the concepts of digital TV broadcasting have been proposed [1, 2]. These concepts are based on the transformation of traditional analog TV to digital multifunction interactive TV broadcast simultaneously providing a number of other telecommunication services. They take into account the necessity to harmonize the use of terrestrial and satellite systems, cable TV and other media to create a single information field for the world community.

There are many different telecommunication systems that use advanced information technologies [3—5]. Such systems have several advantages in comparison with cable or satellite systems. Most important of them are relatively low cost. Microwave integrated multichannel distribution system MITRIS is one of the most prospective. This system operates in frequency band 11.7—12.5 GHz and transmit the radio signals within the coverage radius of 60 km. It ensures environmentally safe levels of radiated power of 3—5 mW for the television programs.

The customer equipment of MITRIS system is very simple compared to that used for satellite reception. Due to the higher power level of the received signal, the receiving antennas are smaller in size, only 250—600 mm in diameter. So they are cheaper and more convenient in operation. Since the antenna is sharply directed, the signals are received only from the transmitter to which it is aimed.

The methods of digital TV programs transmittion for frequencies above 10 GHz are described in the terrestrial and satellite digital broadcast standards. Frequency resources up to 10 GHz inclusive are almost completely exhausted, therefore the efforts of the developers of multimedia systems are directed to frequency bands above 10 GHz. In these frequency bands the multi-carrier mode OFDM (Orthogonal Frequency Division Multiplexing) has significant advantages in comparison with using only one carrier because of the peculiarities of radio signals propagation in different frequency bands.

It should be noted that the OFDM modulation in its pure form is effective for frequencies up to 6 GHz. At higher frequencies in multimedia systems which operate over a wide frequency bands it is possible to use simple types of digital modulation with a relatively low spectral efficiency and high noise immunity. The use of more complex types of modulation, which have significant spectral efficiency, due to increased requirements for frequency stability and phase noise level, as well as the necessity for much greater signal to noise ratio, reduces the energy potential of the system and decreases the radius service area. It is possible to overcome these disadvantages by using well-known combined two-level quadrature-amplitude and frequency modulation (M-QAM/FM) [6, 7].

Design

The combined modulation M-QAM/FM has been applied to improve characteristics of existing MITRIS system in the frequency band 11,7—12,5 GHz. Until recently the system MITRIS used the signals of the DVB-S standard, which was applied in receiver digital satellite TV tuner. Presently MITRIS system is used for broadcast as well as for transfer of large volumes of digital information, and first of all it provides Internet services. The data, that comes from the Internet, by means of router and encapsulator embedded in the DVB structure frame are processed in full compliance with the DVB-S standard and modulate the carrier, forming a constellation of QPSK. Thus, in the transmitting channel the television and the data signals have the same form, although their sources are different originally.

Using QAM-modulation in MITRIS system in accordance with DVB-C standard reduces the radius of action and immunity of the channel that causes further reduction of the service area.

In order to overcome these imperfections another RF signals with multi-position modulation are proposed. In essence, these are the radio channels transmitting FM signals, which distort the restriction level in a microwave transmitter and apply this constraint to eliminate the parasitic amplitude modulation, as well as the FM transmitting signals of usual MITRIS system. The channel noise immunity of the system with two-level modulation is the same as the noise immunity of the analogous channel with frequency modulation. The block diagram of the microwave integrated teleradiocommunication system with secondary frequency modulation is shown in Fig. 1. It indicates the additionally installed equipment and the connections between its elements.

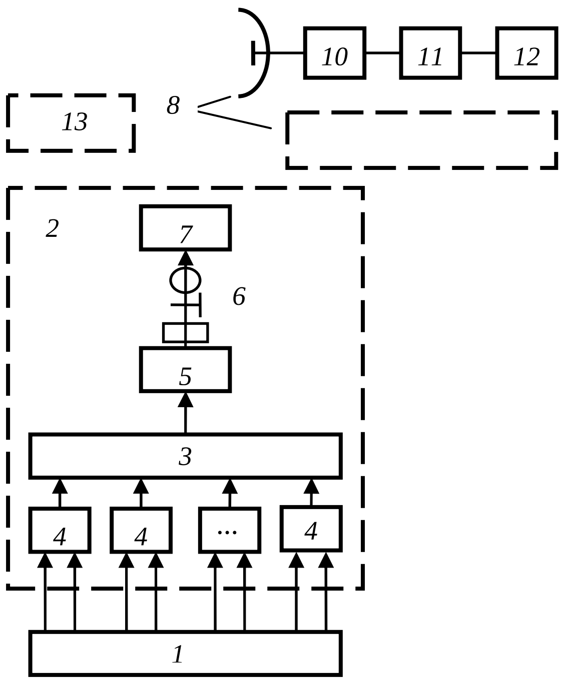

Fig. 1. Block diagram of microwave integrated teleradiocommunication MITRIS system using two-level modulation: (*1*) receiving subsystem of formation and information processing; (*2*) central station; (*3*) programmable converter-shaper to the baseband intermediate frequency; (*4*) combined M-QAM/FM modulator; (*5*) microwave transmitter; (*6*) connecting radiofrequency line; (*7*) antenna system; (*8*) subscriber receiving station; (*9*) antenna subscriber station; (*10*) low-noise converter; (*11*) selective modulator-frequency converter; (*12*) demodulator of DVB-C standard; (*13*) repeater.

Combined M-QAM/FM modulator consists of two modulators, namely the M-QAM modulator, which provides multi-position amplitude-phase modulation, such as 32-QAM, 64-QAM, 128-QAM or 256-QAM, and analog FM modulator, which provides frequency modulation of carrier frequency as for the signal that comes from the M-QAM modulator. M-QAM modulator contains ASI interface (Asynchronous Serial Interface), scrambler, interleaver, immunity encoders Reed — Solomon and Viterbi shaper ensembles of signals, and finally, the actual quadrature M-QAM modulator, that is all those blocks that are necessary to meet the requirements of the DVB-C standard. The signals received from the shaper of the ensemble acquire in the modulator the amplitude and phase modulation of the quadrature components of the carrier frequency in a frequency range from 3 to 11 MHz. These signals together constitute the radio frequency M-QAM signal. It has a 64-QAM modulation and carrier frequency fPCh1 which is equal to 5 MHz. The process of formation of M-QAM signal in the quadrature modulator can be implemented in analog or in digital forms. In the case of a digital modulation the system is terminated on the digital-to-analog converter, so the signal acquires the analog form.

The carrier frequency signal, which was modulated by M-QAM, is directed to second analog modulator, which is used for frequency modulation of carrier fPCh2 having the higher frequency, for instance, 480 MHz as the radio signal M-QAM.

The spectrum of the received signal occupies the frequency band width of approximately 20 MHz. This band is limited by using a filter with the proper bandwidth. The carrier frequency, the level of which depends on the frequency modulation index is present in the spectrum. Other components of the signal spectrum, which are products of the frequency modulation, are limited by the filter.

The central station differs in such a way that the frequency modulators are replaced by the combined modulators M-QAM/FM *4*, and subsystem formation and processing of information *1* is constructed so that its output contains video and audio signals of standard level. Combined modulators *4* run at intermediate frequencies located within the range 0.95—2.15 GHz. Their signals are converted in frequency and are grouped in one multi-frequency signal by means of programmable converter-shaper baseband *3*. The group signal, which occupies the frequency band from 900 MHz to 1900 MHz, comes through frequency converter 5 and feeder 6 to the antenna device *7*.

The difference in the structure of subscriber stations is the availability of new combined device, namely the selective demodulator — the frequency converter. This device consists of the channel selector and auxiliary step-up inverter. The channel selector does not differ from the channel selector of analog tuner for satellite TV. The output of the channel selector receives the signal of the main band with the multiple carrier frequencies in the frequency range 3—11 MHz. One can represent this combined modulated signal as M-QAM signal.

In order to convert the low intermediate frequency into higher frequency at which the signal can be received by means of conventional DVB-C tuner operating in the frequency 480 MHz, it is necessary to use the auxiliary step-up inverter.

The improved MITRIS system has the significantly better energy relations in channel, less stringent requirements for frequency stability and linearity of the amplitude-frequency and phase characteristics of most of the transmitting channels, much bigger phase noise immunity.

Energy relations are much better in channel due to the fact that the SNR of the system with combined modulation is close to those values which correspond to the usual frequency modulation that is 10—12 dB. For comparison, the smallest value of signal to noise ratio for the usual system with 64-QAM is equal to 35 dB. This means that the size of the service area ensured by the system can be increased to three or more times.

Less stringent requirements for frequency stability and phase noise level in the transmitting channel is specified by the use of coherent receiver. In this case, the requirements for frequency stability are those that are valid for digital systems with frequency modulation that is no higher than 10^{-5}. For comparison, for systems that use 64-QAM the frequency stability must be not worse than 10^{-6}.

Lower requirements for linearity of the amplitude-frequency and phase responses of most of the transmitting channels allow using the existing analog MITRIS systems with minimal upgrading for transferring large amounts of digital information, for instance, a large number of TV programs. It ensures the efficient use of radio spectrum without any modifications of the microwave channels equipment.

One more advantage of innovated MITRIS system is its high efficiency in conditions of multipath propagation. For instance, the presence of reflected signals of a certain level does not cause the image disruption.

For direct transmission through the MITRIS system of terrestrial amounts of digital broadcasting signals which are modulated by OFDM according to the DVB-T standard they are further exposed to FM modulation. Such a combined modulation technique is called OFDM/FM. It allows to achieve SNR 10—14 dB while ensuring the proper transfer of information and greatly increase the range of communication. In this case, complex types of modulation are used only in short segments of the signal processing path, where conditions for transmission and reception are much easier to implement.

In the live channels and more high-frequency part of the equipment through the use of frequency modulation, there are much softer demands to the linearity of the amplitude and phase characteristics of the transmitting and receiving paths, to the frequency stability and phase noise level of equipment as well as to the quality of radio with respect to fading and group delay.

Conclusion

Using a combined two-level modulation M-QAM/FM the upgrading of the existing MITRIS systems are successfully performed. The result obtained can be applied to the construction of new interactive multimedia systems and other MITRIS systems. They provide new advantages in transmitting of digital signals with complex types of modulation through the channels, which are intended to send only analog signals, and ensure a significant increase of the spectral efficiency of systems that operate at frequencies above 10 GHz. This method has great potential for upgrading of existing systems of microwave transmission and can be recommended for the use in satellite communications and other radio systems.

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