TTCM Burst-by-Burst Adaptive Wideband Coded Modulation in Rayleigh Channel

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Abstract

The concept of wideband coded modulation has been in existence for many years. It was predominately utilized in many applications due to its inherent resistance to noise, including jamming and low probability of intercept. For this reason, it was the communication method of choice in various situations. The TTCM has been shown to be more efficient than TCM for transmissions over AWGN channels and narrowband fading channels. The multi-path channel model is characterized by its discretized symbol-spaced COST207 Typical Urban (TU) channel impulse response. The Rayleigh multipath channel is also discretized. Therefore, OTHMA can be applied as a multiple access scheme for low power, large scale, and low activity networks in UWB impulse radio communications. The performance of TTCM Burst-by-Burst Adaptive Wideband Coded Modulation system is tested in a Semi-realistic channel model that is based on an extensive set of outdoor channel measurements. Through semi-analytical evaluations of the bit error probability, we show that the TTCM Burst-by-Burst Adaptive Wideband Coded Modulation system is almost has good BER performance. Also, a comparison between the BER performances of many channels has been done.

Keywords: COST207, TTCM, Burst-by-Burst, Rayleigh

النظام المتكيف المشفر ذو الحزمة العريضه في قناة رايلي

المستلخص

لقد كان مفهوم تضمين ترميز النطاق العريض موجود لسنوات عديده. وقد استخدم في الغالب في كثير من التطبيقات بسبب المقاومة الكامنه للضوضاء، بما في ذلك التشويش واحتمال ضعيف للاعتراض. لهذا السبب كانت هي طريقة الاتصال التي يختارونها في مختلف الحالات. وقد تبين ان TTCM لتكون اكثر كفاءة من TCM التقليدي لنقل الحركة عبر قنوات AWGN وقنوات التلاشي الضيقة. وتتميز القناة ذات المسار المتعدد النمط التي لها Discretized رموز متعددة النموذجية في المناطق الحضرية COST207 استجابة نبضة قناة. كذلك قناة رالي المتعددة هي ايضا TU ولذلك يمكن تطبيق OTHMA كمشروع متعدد للحصول على الطاقة المنخفضة على نطاق واسع وشبكات انخفاض النشاط في مجال الاتصالات UWB. يتم اختبار اداء انفجار تلو انفجار Burst-by-Burst التكييف المتسع لنظام ترميز التحوير في نموذج قناة شبه واقعية تقوم على مجموعة واسعة من القياسات في قناة تعمل في الفضاء الحر من خلال تقييم شبه التحليل من احتمال الـ Bit الخطا. وتبين لنا الـ Burst-by-Burst باستخدام القناة رالي هو الافضل من حيث نتائج الاداء مقارنة مع قنوات عديده.

1. Introduction

The Trellis Coded Modulation (TCM), which is based on combining the functions of coding and modulation, is a bandwidth efficient scheme that has been widely recognized as an excellent error control technique suitable for applications in mobile communications. Turbo Trellis Coded Modulation (TTCM) is a more recent channel coding scheme that has a structure similar to that of the family of power efficient binary turbo codes, but employs TCM codes as component codes. The Rate 2/3 TTCM was to be 0.5 dB better in Signal-to-Noise Ratio (SNR) terms, than binary turbo codes over AWGN channels using 8-level Phase Shift Keying (8PSK) [1]. TTCM was also shown to outperform a similar-complexity TCM scheme in the context of Orthogonal Frequency Division Multiplexing (OFDM) transmission over various dispersive channels. In this latter context, the individual OFDM subcarriers experienced effectively narrowband fading and the TCM as well as TTCM complexity were rendered similar by adjusting the number of turbo iterations and code constraint length. However, the above fixed mode transceiver failed to exploit the time varying nature of the mobile radio channel. By contrast, in BbB adaptive schemes 1671 a higher order modulation mode is employed, when the instantaneous estimated channel quality is high in order to increase the number of Bits Per Symbol (BPS) transmitted and conversely, a more robust lower order modulation mode is employed, when the instantaneous channel quality is low, in order to improve the mean Bit Error Rate (BER) performance. Un coded adaptive schemes and coded adaptive schemes have been investigated for narrowband fading channels. Finally, a turbo coded wideband adaptive scheme assisted by Decision Feedback Equalizer (DFE) was investigated in. In our practical approach the transmitter obtains the channel quality estimate generated by receiver B upon receiving the transmission of transmitter B. In other words, the modem mode required by receiver B is superimposed on the transmission burst of transmitter B. Hence a delay of one transmission burst duration s incurred. In the literature, adaptive coding for time-varying channels using outdated fading estimates has been investigated. Over wideband fading channels the DFE employed will eliminate most of the Inter-symbol Interference (ISI). Consequently, the Mean-Squared Error (MSE) at the output of the DFE can be calculated and used as the metric invoked to switch the modulation modes. This ensures that the performance is optimized by employing equalization and BbB adaptive TCM/TTCM jointly, in order to combat the signal power fluctuations of the wideband channel [1,2].

This paper is characterized as follows: In Section 2, the Multipath Rayleigh Fading Channel is previewed. In Section 3, the System Overview and Setup Parameters is presented. Section 4, the Performance of the Fixed Modem Modes is presented. In Section 5, the Performance of System with Rayleigh and COST 207 channels is presented. Section 6 presents the Performance of System with Rayleigh and AWGN channels. And finally, the conclusion points are given in Section 7.

2. Multipath Rayleigh Fading Channel

There are times when a mobile receiver is completely out of sight of the base station transmitter (i.e., there is no signal path traveling to the receiver via LOS). In this case, the received signals are made up of a group of reflections from objects, and none of the reflected paths is any more dominant than the other ones. The different reflected signal paths arrive at slightly different times, with different amplitudes, and with different phases. It was verified, both theoretically and experimentally, that the envelope of a received carrier signal for a moving mobile is Rayleigh distributed. Therefore, this type of fading is called Rayleigh fading. The theoretical model makes use of the fact that there are many reflected signal paths from different directions (i.e., N signal paths). The composite received signal is:

$$r(t) = \sum_{n=1}^{N} R_n \cos\left(2\pi f t - 2\pi f_{D,n} t\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (1)$$

Note that the received signal is made up of N reflected signals; each reflected path has an amplitude of R_n and f is the carrier frequency. The frequency shift of each reflected signal is due to the Doppler effect when the mobile user is in motion. If the signal is traveling parallel to the mobile's direction of motion, then the Doppler frequency shift $f_{D,n}$ is given by [3]:

$$f_{D,n} = \frac{v}{\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (2)$$

where v is the velocity of the mobile.

Multipath fading is due to the constructive and destructive combination of randomly delayed, reflected, scattered, and diffracted signal components. This type of fading is relatively fast and is therefore responsible for the short-term signal variations. Depending on the nature of the radio propagation environment, there are different models describing the statistical behavior of the multipath fading envelope [4].

When the channel impulse response $c\,(\tau, t)$ at a delay τ and time instant t is modeled as a zero-mean complex-valued Gaussian distribution, the envelope $|c\,(\tau, t)|$ at that time instant t is known to be Rayleigh distributed. In this case the channel is said to be a Rayleigh fading channel. The Rayleigh distribution has the probability density function (PDF) as [5]:

$$p(r) = \begin{cases} \frac{r}{\alpha^2} \exp\left(-\frac{r^2}{2\alpha^2}\right) & (0 \leq r \leq \infty) \\ 0 & (r < 0) \end{cases} \quad \text{………………………….} \quad (3)$$

where r is the envelope of the received signal and α^2 is the time average power of the received signal before envelope detection.

3. System Overview and Setup Parameters

The multi-path channel model is characterized by its discretized symbol-spaced Rayleigh channel impulse response. Each path is faded independently according to a Rayleigh distribution and the corresponding normalized Doppler frequency is 4.5, the system Baud rate is 5.3 MBd, the carrier frequency is 2.8 GHz and the vehicular speed is 100 km/h. The DFE incorporated 44 feed-forward taps and 9 feedback taps and the transmission burst structure used is shown in Figure (1). When considering a Time Division Multiple Access (TDMA)/Time Division Duplex (TDD) system of 16 slots per 4.615 TDMA frame, the transmission burst duration is 288 PS, as specified in the Pan-European FRAMES proposal. The following assumptions are assumed. Firstly, the equalizers capablling of estimating the Channel Impulse Response (CIR) perfectly from the equalizer training sequence of Figure (1).

Secondly, the CIR is time-invariant for the duration of a transmission burst, but varies from burst to burst according to the Doppler frequency, which corresponds to assuming that the CIR is slowly varying. The error propagation of the DFE will degrade the estimated performance, but the effect of error propagation is left for further study.

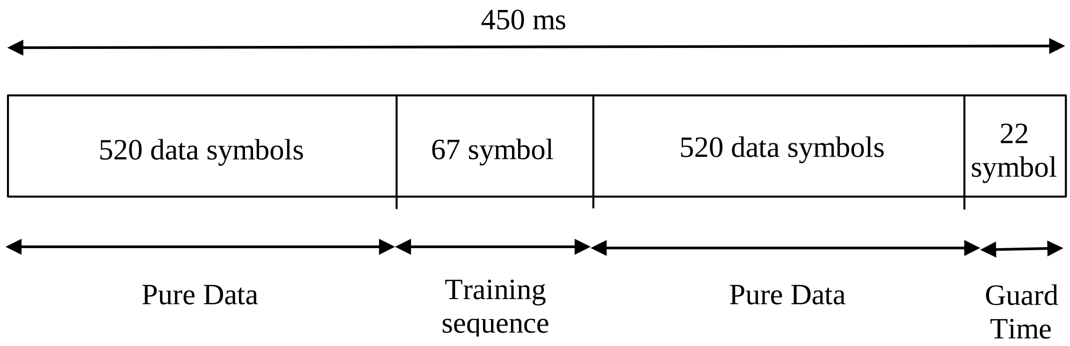

Figure (1). Transmission Data Burst.

At the receiver, the CIR is estimated, which is then used to calculate the DFE coefficients. Subsequently, the DFE is used to equalize the Inter-symbol Interference (ISI)-corrupted received signal. In addition, both the CIR estimate and the DFE feed-forward coefficients utilized to compute the SNR at the output of the DFE. More specifically, by assuming that the residual IS1 is near-Gaussian distributed and that the probability of decision feedback errors is negligible, the SNR at the output of the DFE, is calculated as:

$$\gamma_{dfe} = \frac{Wanted\ Signal\ Power}{Residual\ ISI\ Power + Effective\ Noise\ Power} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$\gamma_{dfe} = \frac{E\left[\left|s_k \sum_{m=0}^{N_f} C_m\, h_m\right|^2\right]}{\sum_{q=-(N_f-1)}^{-1} E\left[\left|\sum_{m=0}^{N_f-1} C_m\, h_m s_{k-q}\right|^2\right] + N_0 \sum_{m=0}^{N_f} |C_m|^2} \quad \ldots\ldots\ldots. \quad (5)$$

where C, and h, denotes the DFE's feed-forward coefficients and the CIR, respectively. The transmitted signal is represented by s_k and N_0 denotes the noise spectral density.

The equalizer's SNR, γ_{dfe}, in Eq. 5, is then compared against a set of adaptive modem mode switching thresholds fn, and subsequently the appropriate modulation mode is selected. The modem mode required by receiver *B* is then fed-back to transmitter A. The modulation modes that are utilized in this scheme are, 8PSK, 16QAM and 256QAM. The simplified block diagram of the adaptive system is shown in Fig. (2) [6], where no channel interleaving is used. Transmitter A extracts the modulation mode required by receiver B from the reverse-link transmission burst in order to adjust the adaptive TCM/TTCM mode suitable for the channel. This incurs one TDMN/TDD frame delay between estimating the actual channel condition at receiver B and the selected modulation mode of transmitter A. Four encoders are invoked, each adding one parity bit to each information symbol, yielding the coding rate of 323 in conjunction with the TCM/TTCM mode of 114 for 8PSK, 335 for 16QAM and 760 for 256QAM. The design of TCM schemes for fading channels relies on the time and space diversity provided by the associated coder.

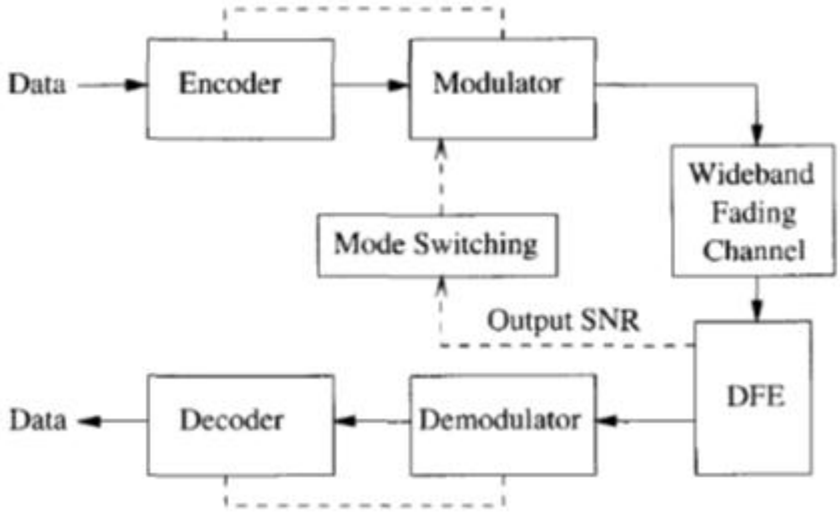

Figure (2). The burst-by-burst System without channel inter leaver.

4. Performance of the Fixed Modem Modes

In this section, the BER performance of the system with Rayleigh channel using fixed modem modes of 16QPSK, 64QAM and 256QAM are studied both with and without channel interleavers. These results are shown in Figure (3) for TCM. The random “CM symbol-interleaver memory was set to 684 symbols, where the corresponding number of bits was the number of data bits per symbol (BPS) x 775. A channel interleaver of 6 x 775 symbols was utilized, where the number of bits was (BPS + 1) x 4 x 775 bits, since one parity bit was added to each TCM/TTCM symbol. As shown in Figure (5), the BER performance of the channel-interleaved case is superior compared to that without channel interleaver in the case of 16QPSK.

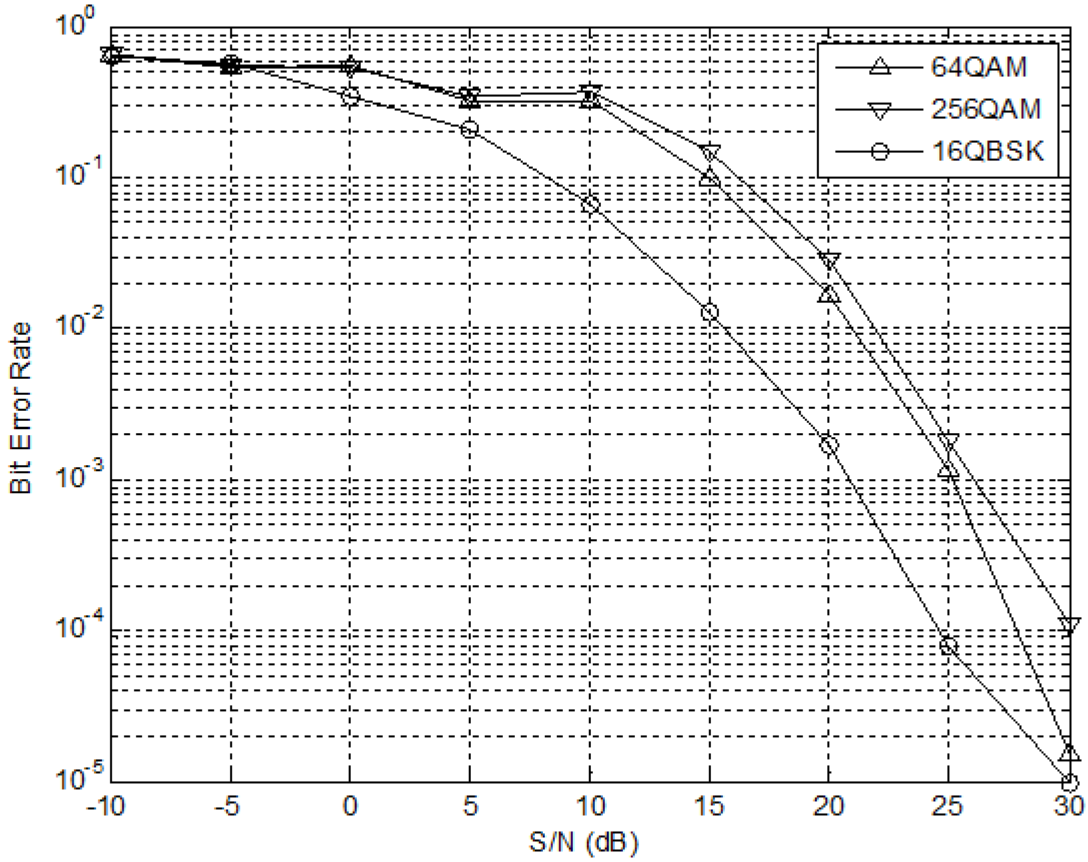

Figure (3). The BER performance for various modulation schemes.

The performance results is also shown in Table (1) for $= 10^{-4}$.

Table (1). The S/N ratio for various modulation schemes.

The modulation Scheme	S/N (dB)
64 QAM	25
256QAM	28
16QBSK	---

5. Performance of System with Rayleigh and COST 207 channels

The BER performance of the adaptive TTCM system using 4 iterations is shown in Figure (4) with Rayleigh and COST 207 [7] channels. In order to investigate the switching dynamic of the systems, the mode switching together with the equalizer's output SNR is setup to 17 dB. As we notice from the figure, the BER performance of the system has a lower values with Rayleigh channel.

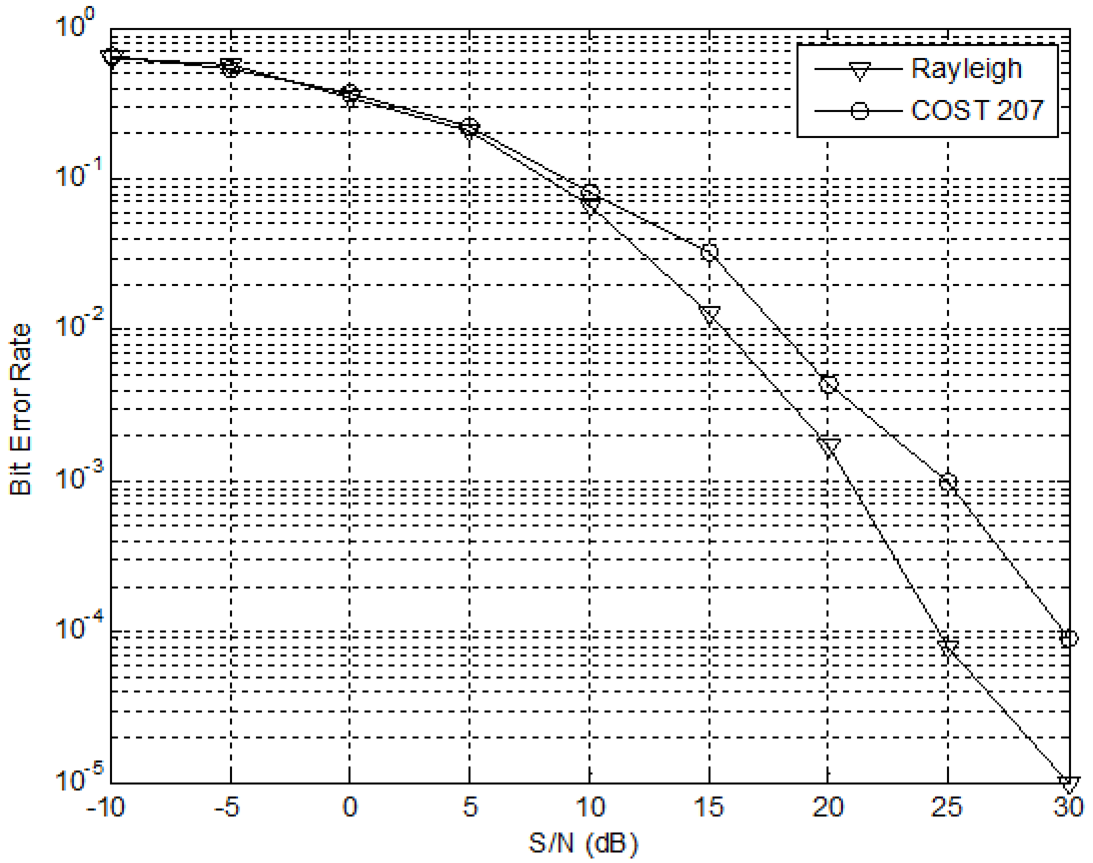

Figure (4). The System BER performance with Rayleigh and COST 207.

The performance results is also shown in Table (2) for $= 10^{-4}$.

Table (2). The S/N ratio for various channels.

The Channel Type	S/N (dB)
Rayleigh	24
COST 207	30

6. Performance of System with Rayleigh and AWGN channels

Again, the system performance is also tested in transmissions over AWGN channel and Rayleigh channels using 16QPSK scheme. Figure (5) shows the results. As we notice from the figure that the system BER with AWGN channel is outperformed the system performance with Rayleigh channel.

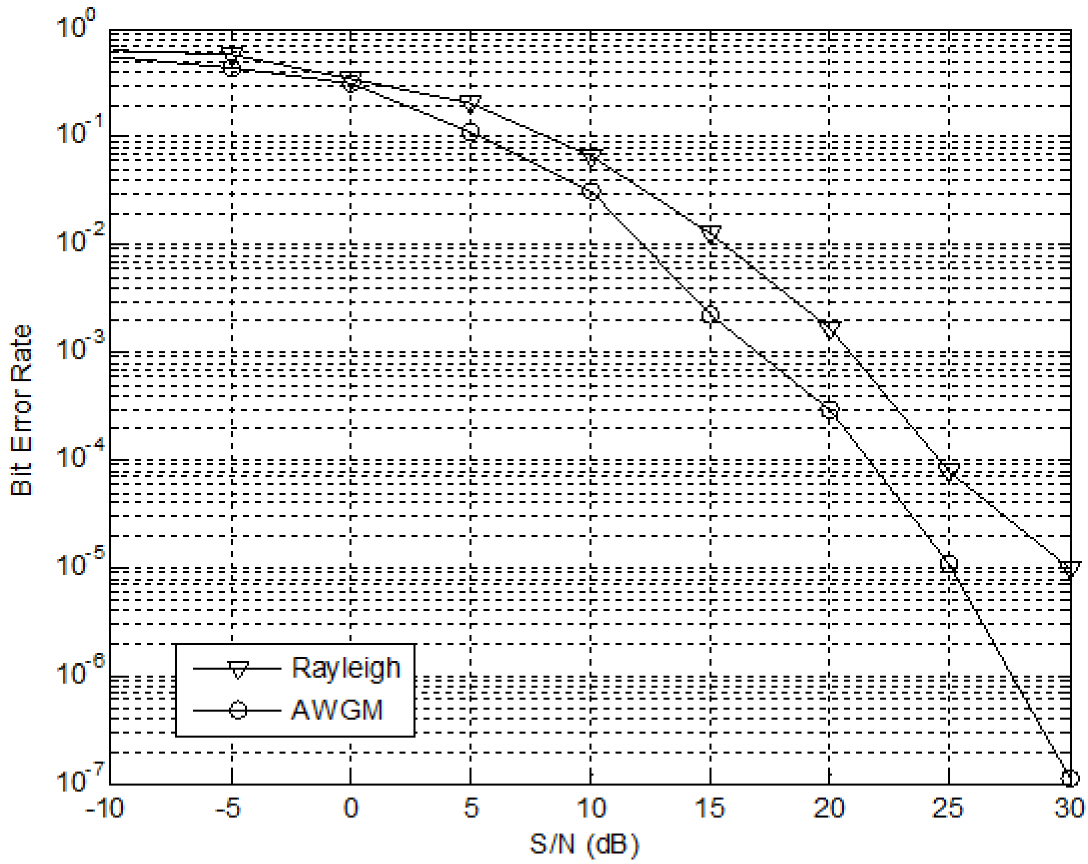

Figure (5): The System BER performance with Rayleigh and AWGN channels.

The performance results is also shown in Table (3) for $= 10^{-4}$.

Table (3). The S/N ratio for various chann*els*

The Channel Type	S/N (dB)
Rayleigh	24
AWGN	30

7. Conclusions

In the presented research, the TTCM Burst-by-Burst Adaptive Wideband Coded Modulation system tested in Rayleigh Channel.

Many important points can be noted during simulation and discussion of the results of the system with Rayleigh fading channel.

First, the system has gained a lower BER values by using 16QPSK modulation scheme. Second, the system is work better in Rayleigh multipath channel. Finally, a good performance is obtained with the AWGN channel.

8. References

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