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Spectral Efficiency Analysis of Digital Signals for 3.1–10.6 GHz Ultra-Wideband Radio Systems

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Abstract—Spectral efficiency analysis of widely used types of digital signals in the 3.1–10.6 GHz frequency band is presented. Peculiarities of energy accumulation in the specified frequency band are demonstrated for video signals and modulated signals. Optimal durations, which provide maximum value of spectral efficiency, of the considered video signals are determined. Practical recommendations on using the considered digital signals in the 3.1–10.6 GHz ultra-wideband radio systems are concluded.

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INTRODUCTION

Ultra-wideband (UWB) radio systems are a perspective and dynamically progressing sphere of modern radio engineering. This primarily applies to ultra-wideband radars, radio electronic warfare, electromagnetic monitoring and high-speed data transfer.

One of the documents governing the application of UWB techniques for high-speed data transfer over short distances is [1], where the 3.1–10.6 GHz frequency band is dedicated for these purposes. Obviously, the efficiency of using the specified bandwidth is directly connected to the choice of optimal digital signals with corresponding spectral characteristics.

In [2] the notion of spectral efficiency coefficient is introduced as a fraction of signal's energy concentrated in the radio system's operating bandwidth. In the same work the notion of spectral efficiency coefficient is used to analyze probing pulses in UWB radars. Authors of [3] independently from the authors of [2] came to the notion of spectral efficiency, which they used to study digital modulated signals in order to find the limiting ratio of symbol rate to minimal carrier frequency in UWB radio systems.

This article aims to study spectral efficiency of widely used digital video and modulated signals for UWB radio systems operating in the 3.1–10.6 GHz frequency band.

PROBLEM DEFINITION

Historically the first message symbols for UWB systems, which initially were also called carrier-less, were video signals, out of which we'll consider rectangular, triangular and Gaussian video pulses, as well as sine half-period. An obvious fact that these signals contain a substantial DC component, which cannot be radiated by antennas, negatively impacts their spectral efficiency. Due to this later UWB systems started using meander (square wave), Gaussian monopulse and one sine period. Study of these signals is also of practical interest. More over the authors investigate spectral efficiency of Gaussian pulse derivatives, which, according to some works (for example, [4]), possess advantageous spectral properties that allow using them in UWB radio systems. Finally, we consider classical modulated signals and show that despite the opinion of some authors (for example, [5]) that modulated signals are inappropriate for UWB systems, their spectral efficiency characteristics significantly differ from the properties of video signals. Modulates signals are appropriate for use in 3.1–10.6 GHz UWB radio systems.

We define spectral efficiency $\eta(\tau)$ of a digital signal $s(t)$ with duration τ as a fraction of energy concentrated in the frequency band $[\omega_{lw}, \omega_{up}]$ using formula [2, 3]