Spectrum Suppressed Transmission Applied by Higher Coding Rate FEC

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Abstract**—** Spectrum suppressed transmission is one of the most effective schemes to increase frequency utilization efficiency by making its required bandwidth narrower than the Nyquist bandwidth. In this scheme, ISI(Inter Symbol Interference) caused by spectrum suppression makes its transmission quality worse, so an FEC(Forward Error Correction) must be needed. However, the previous studies of the spectrum suppressed transmission have been limited to the usages of higher coding gain FECs. In this paper, we propose the spectrum suppressed transmission applied by higher coding rate FEC with a coding rate of three-fourth and its frequency utilization efficiency increases are clarified by computer simulations.

Keywords**—** *spectrum suppression transmission, ISI, higher coding rate FEC, frequency utilization efficiency*

I. Introduction

Currently, with the spread of various wireless communication systems, most of frequency bands are assigned to the existing wireless communication systems and there is no frequency bandwidth for new wireless systems[1]. In addition, with the recent consideration of NTN(Non-Terrestrial Network)[2], the depletion of frequency bandwidth would become a same problem even in satellite communications. In order to solve this problem, frequency utilization efficiency as defined by Equation(1) must be increased.

$$Frequency \text{ utilization efficiency} = \frac{Throughput}{Required\ bandwidth} \quad (1)$$

There are two ways to increase frequency utilization efficiency. One is to increase the throughputs without the required bandwidth expansions such as multi-level modulations[3] and MIMO(Multiple-Input Multiple-Output) transmissions[4]. Although multi-level modulations can increase the throughputs, higher modulation accuracies are required for hardware implementation because the distances between transmission signals become shorter as the number of modulation level increases. MIMO transmission can increase the throughputs by increasing the numbers of both transmitting and receiving antennas, but it is difficult to be implemented in small mobile terminals.

On the other hand, spectrum suppressed transmission suppresses its required bandwidth narrower than the Nyquist bandwidth while maintaining the throughputs as much as possible[5]. It is regarded as one of FTN(Faster than Nyquist) techniques[6]. It can simply be implemented by only inserting a suppression filter into the transmitter, so the existing equipment can still be used. Therefore, it can quickly address the problem of frequency depletion.

In spectrum suppressed transmission, an FEC(Forward Error Correction) must be needed because the transmission quality degrades due to ISI(Inter Symbol Interference) caused by spectrum suppression. However, the previous studies of spectrum suppressed transmission have been limited to the application of high coding gain FECs[5][7], which are popular FECs in satellite communications[8]. However, concerning on frequency utilization efficiency, there is a trade-off between coding rate and suppressed bandwidth. Therefore, it is necessary to clarify the performances with high coding rate FECs.

In this paper, we propose the spectrum suppressed transmission applied by a higher coding rate FEC with a coding rate three-fourth and its frequency utilization efficiency increases are clarified by computer simulations.

II. SPECTRUM SUPPRESSED TRANSMISSION

Spectrum suppressed transmission is a scheme to increase frequency utilization efficiency by making the required bandwidth suppression narrower than the Nyquist bandwidth by using a suppression filter while maintaining the throughputs as much as possible[5]. Figure 1 shows an image of spectrum suppression. This is an example of single-carrier modulation. Since the Nyquist bandwidth defined by 3dB bandwidth is f_N, the required bandwidth after spectrum suppression is f_S, the suppression ratio r_s is defined by Equation(2).

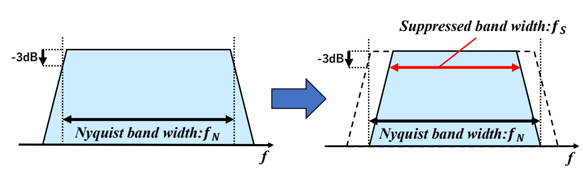

Figure 1 An image of spectrum suppression.

$$r_s = \frac{f_N - f_S}{f_N} \quad (2)$$

Here, the required bandwidth of the transmitted signal becomes narrow than the Nyquist bandwidth, so this is regarded as one of FTN techniques that allow ISIs to be transmitted[6]. In this scheme, an FEC must be needed to improve the transmission quality degradation due to ISI caused by spectrum suppression.

In Reference[7], spectrum suppressed transmission have been reported. Figure 2 shows spectra, eye patterns and constellations without/with spectrum suppression. From this figure, by using 10% spectrum suppression, eye pattern and constellation are degraded compared to those without spectrum suppression. Figure 3 shows relationship between r_s and frequency utilization efficiency of the conventional scheme. By using an FEC coding rate of one-half, the conventional spectrum suppressed transmission can obtain a maximum frequency utilization efficiency of 1.43 bit/sec/Hz compared to 1.00 bit/sec/Hz by no spectrum suppression.

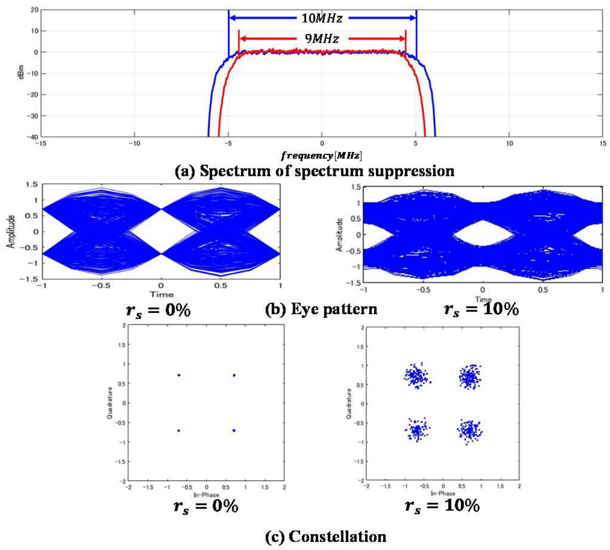

Figure 2 Spectrum, eye patterns and constellations

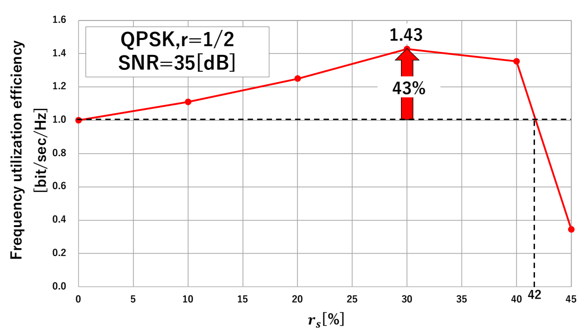

Figure 3 Relationship between r_s and frequency utilization efficiency of the conventional scheme (QPSK, r=1/2).

III. NEW PROPOSAL

A. Simulation Block Diagram of the Proposed Scheme

In this paper, we propose a spectrum suppressed transmission applied by a higher coding rate FEC with a coding rate of three-fourth and its frequency utilization efficiency increases are clarified by computer simulations.

The simulation block diagram of the proposed scheme is shown in Figure 4. Table 1 shows the major simulation parameters. The modulation schemes are single-carrier QPSK and 16QAM with a symbol rate of 10Msymbol/sec and an FEC coding rate of three-fourth. A root roll-off filter with a raised-cosine characteristic with a roll-off factor α=0.2 is used for the waveform shaping, and the suppression filter is

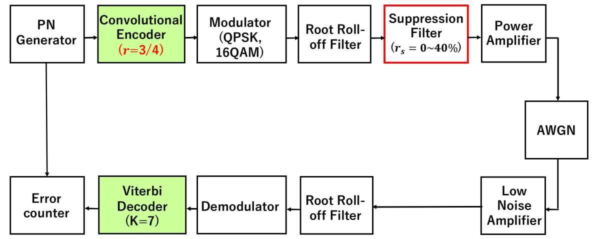

Figure 4 Simulation block diagram of the proposed scheme.

TABLE 1 MAJOR SIMULATION PARAMETERS

Parameter	Value	
Modulator scheme	QPSK	16QAM
Symbol rate	10Msymbol/sec	
Root roll-off filter	129 tap FIR filter Bandpass filter Raised cosine characteristics ($\alpha = 0.2$)	
Suppression filter	129 tap FIR filter Bandpass filter Raised cosine characteristics (Equivalent to $\alpha = 0.2$)	
Suppression ratio	0~40%	
Power amplifier	Linear	
Propagation path model	AWGN	
FEC	Convolution coding($r = 3/4$, $K = 7$) Viterbi decoding(3bit soft decision)	

equivalent to α=0.2 as the same attenuation characteristics as the waveform shaping filter. In addition, this scheme maintains the transmission power per bit(E_b) before and after the suppression filter by re-assigning the suppressed power by the suppression filter to the residual spectrum to be transmitted[5]. The proposed scheme uses convolutional coding with a coding rate of three-fourth and Viterbi decoding(3bit soft decision) instead of the conventional high coding gain FECs.

B. Simulation results of the proposed scheme

First, Figure 5 shows BER performances of the proposed spectrum suppressed transmission with QPSK. The orange solid line shows the BER performance without spectrum suppression. From this figure, although the BER performances become worse as r_s increases, the required SNR at BER=10^{-4} keeps 7.2dB even in the condition of r_s=10%. This is just required SNR degradation of 1.1dB.

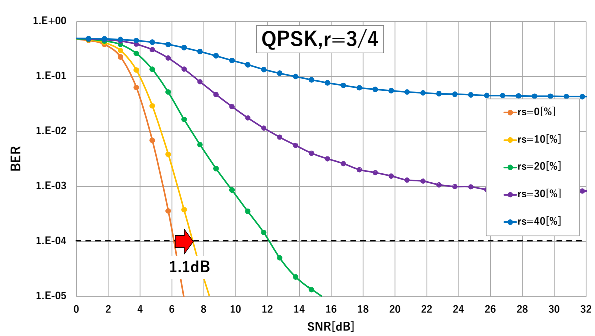

Figure 5 BER performances of the spectrum suppressed transmission with QPSK.

Figure 6 shows relationship between r_s and frequency utilization efficiency of the proposed scheme with QPSK. The frequency utilization efficiency without suppression(r_s=0%)

is 1.50 bits/sec/Hz by using QPSK with r=3/4. For example, when the required SNR=35dB, the proposed scheme can obtain higher frequency utilization efficiency compared to that without spectrum suppression in the r_s range up to 24%. Moreover, a maximum frequency utilization efficiency of 1.88 bits/sec/Hz can be achieved by the proposed scheme with r_s= 20%. This is 25% higher than that without spectrum suppression.

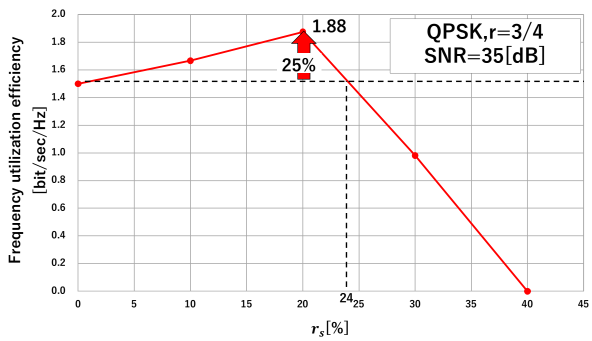

Figure 6 Relationship between r_s and frequency utilization efficiency of the proposed scheme with QPSK.

C. *Simulation results of 16QAM*

As well as QPSK, the required SNR with 16QAM maintains 14.6dB even in the condition of r_s=5% from figure 7. This is just required SNR degradation of 2.3dB. And then from figure 8, the proposed scheme can obtain higher frequency utilization efficiency up to r_s =9%. Also, a maximum frequency utilization efficiency of 3.16 bits/sec/Hz is obtained by r_s= 5%.

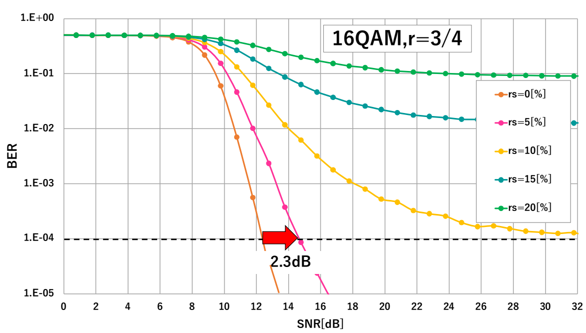

Figure 7 BER performances of the proposed scheme with 16QAM.

D. *Effect of Higher Coding Ratio on Frequency Utilization Efficiency*

Finally, Figure 9 shows maximum frequency utilization efficiency with spectrum suppressed transmission. The maximum frequency utilization efficiency with suppression(r_s=20%) is 1.88 bit/sec/Hz by using QPSK with r=3/4 compared to 1.43 bit /sec/Hz by using QPSK with r=1/2. Similarly, in the case of 16QAM, the proposed scheme can obtain the maximum frequency utilization efficiency 3.16 bit/sec/Hz at r_s=30% compared to 2.26 bit/sec/Hz with r=1/2. Therefore, spectrum suppressed transmission with r=3/4 FEC increases frequency utilization efficiency compared to that with r=1/2.

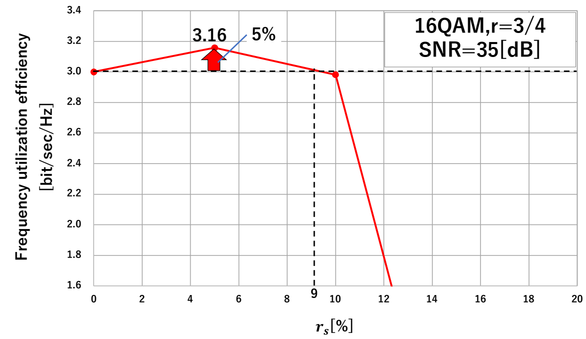

Figure 8 Relationship between r_s and frequency utilization efficiency of the proposed with 16QAM.

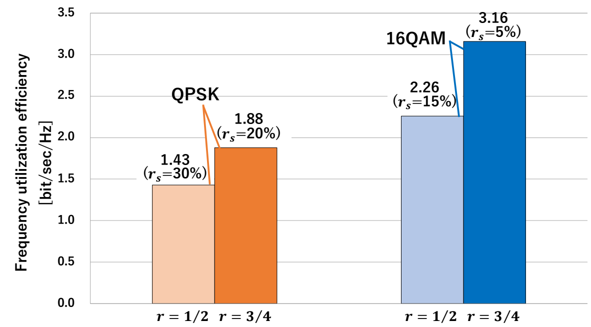

Figure 9 Maximum frequency utilization efficiency with spectrum suppressed transmission.

IV. Conclusion

In this paper, we have proposed the spectrum suppressed transmission applied by a higher coding rate FEC with a coding rate of three-fourth and its frequency utilization efficiency increases have been clarified by computer simulations. The results show that applying r=3/4 FEC has increased frequency utilization efficiency by 25% for QPSK, 5% for 16QAM compared to those with r=1/2 FEC.

Conclusion, it was found that spectrum suppressed transmission with r=3/4 can improve frequency utilization efficiency.

In the future, we will evaluate the performances of the spectrum suppressed transmission applied by other FECs selected for existing mobile communication standards.

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