Spectrum Suppressed Transmission Scheme for Higher Frequency Utilization Efficiency

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Abstract

In this article, we introduce a spectrum suppressed transmission scheme as one of the most promising technologies for increasing frequency utilization efficiency in order to overcome the shortage of frequency resources experienced by various wireless systems. It should provide simultaneous frequency sharing among multiple wireless communication systems.

1. Introduction

Higher transmission speeds are needed for wireless communication systems to support rich communication applications. However, the popularity of various wireless systems has led to a shortage of frequency resources, which is becoming a severe problem and affecting the introduction of new wireless systems and the spread of wireless equipment. An example of conventional frequency allocation is shown in **Fig. 1**. This method assigns dedicated frequency bandwidth for each wireless system and also provides a frequency guard band between the systems to prevent mutual interference. However, demand for wireless communication systems will exceed their capacity because of the high demand for wireless data traffic and the lack of frequency resources. Therefore, NTT Access Network Service Systems Laboratories is considering the need for simultaneous frequency sharing among various wireless communication systems in the near future.

Trials of frequency sharing among wireless communication systems have already been started. For example, the 2.4-GHz frequency band, designated as the industrial, scientific, and medical (ISM) band, which is license-free, is used by lots of electronic hardware including Wi-Fi devices and microwave ovens. But existing frequency sharing methods are based on collision avoidance as typified by CSMA/CA (carrier sense multiple access/collision avoidance), so a system must wait to transmit signals while other systems are transmitting. They just use a form of separation in time for wireless systems using the same frequency band. Frequency-band sharing at the same time and same location is what is required in order to solve the frequency shortage problem fundamentally.

2. Spectrum suppressed transmission scheme

NTT Access Network Service Systems Laboratories is developing a spectrum suppressed transmission scheme as one of the key technologies for achieving frequency sharing among various wireless communication systems [1]. The scheme's frequency allocation for two wireless communication systems is shown in **Fig. 2**. It allows spectra to overlap in the frequency domain so that the total occupied bandwidth (f'_{all}) is narrower than that in the conventional frequency allocation method (f_{all}). The transmission bit rate is maintained because the wireless interfaces, including the symbol rate and modulation type, are not changed at all. Thus, the frequency utilization efficiency is increased because the total occupied bandwidth is narrower for the same transmission bit rate.

However, the communication quality could be

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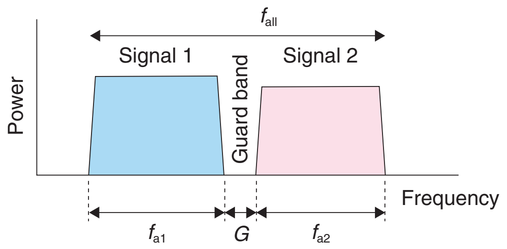
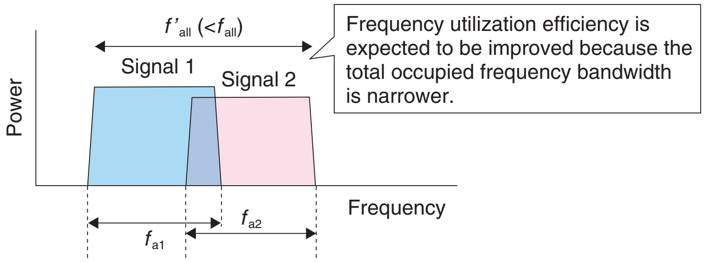


Fig. 1. Conventional frequency allocation.



Frequency utilization efficiency is expected to be improved because the total occupied frequency bandwidth is narrower.

Fig. 2. New frequency allocation.

degraded by mutual radio interference in the overlapped frequency bandwidth. To address this problem, we have devised an interference suppression technique suitable for wireless transmitters and receivers [2]. The following sections describe the processing in detail and present results for an evaluation of the increase in frequency utilization efficiency.

3. Spectrum suppression technology

In this section, we introduce our spectrum suppression technique for multicarrier signaling. Here, we assume that orthogonal frequency division multiplexing (OFDM) is used for the multicarrier signaling. OFDM, which transmits data in parallel on multiple subcarriers, has recently begun to be used in various high-speed mobile communication systems including Wi-Fi, WiMAX (Worldwide Interoperability for Microwave Access), and LTE (Long Term Evolution), owing to its high frequency utilization efficiency and tolerance to multipath fading. These OFDM systems normally use forward error correction (FEC) coding/decoding to improve communication quality in wireless environments that have a high error rate, as shown in **Fig. 3**. This is called COFDM (coded OFDM).

3.1 Spectrum suppression at the transmitter

Our scheme suppresses the overlap frequency bandwidth before transmission to achieve simultaneous frequency sharing without radio interference (**Fig. 4**). Although it is achieved by passing the signal through a filter, it could also be easily achieved by setting the transmission power of particular subcarriers to zero when OFDM is used. Note that suppression rate α is defined as the ratio of the suppressed bandwidth to the bandwidth originally used by the signal. The transmission bit rate can be kept at that of the non-suppressed signal while some of the subcarriers are suppressed.

3.2 Spectrum suppression at the receiver

In the FEC decoder, some information called likelihood, which reflects whether a transmitted binary digit (bit) is more likely to be 0 or 1, is used for error correction processing. The likelihood is calculated in the subcarrier demodulation process. When the log-likelihood ratio (LLR) is used as the likelihood metric, a larger absolute value is assigned to received bits on subcarriers whose reception power is higher. Similarly, a smaller absolute value is assigned to bits on lower-power subcarriers. Positive and negative values correspond to whether the bit is more likely to be 0 or 1. The proper likelihood for the suppressed

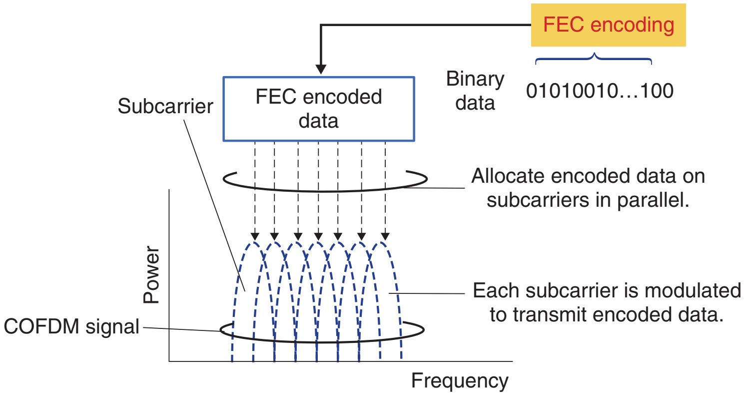


Fig. 3. COFDM signal.

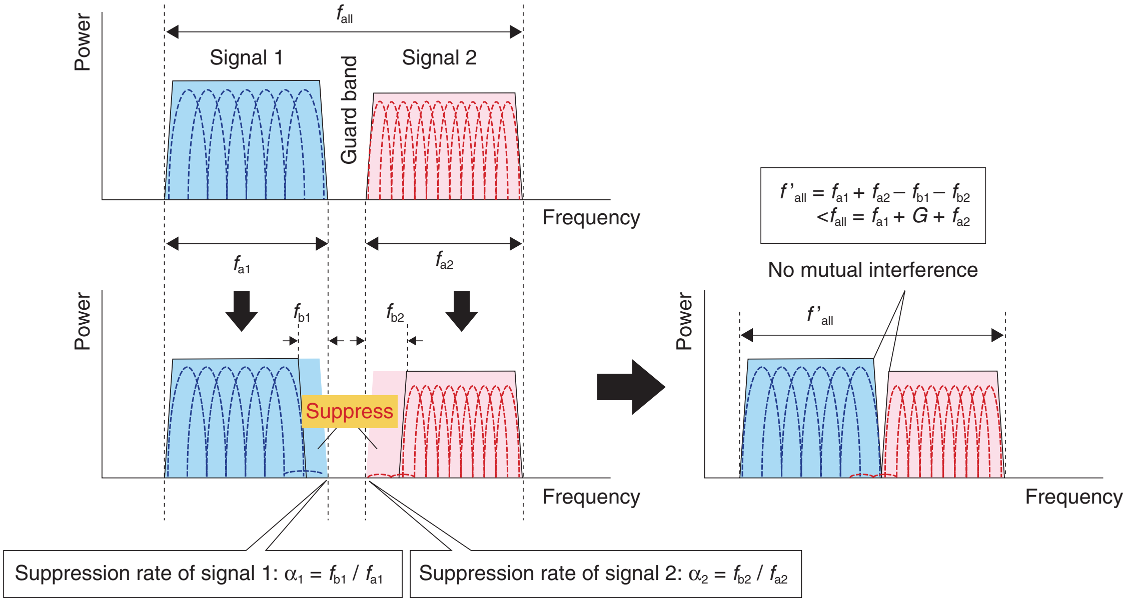


Fig. 4. Narrowing of the occupied bandwidth by spectrum suppression at the transmitter.

subcarriers has an extremely low absolute value because no information is transmitted on suppressed subcarriers. Unfortunately, when the reception power of an interference signal is relatively high, the likelihood for suppressed subcarriers is calculated as a large absolute value, as shown in **Fig. 5**. This results in wrong error correction and causes degradation in the reception performance.

To overcome this problem, we implement FEC metric masking in the receiver. This technique simply replaces the likelihood for suppressed subcarriers by a neutral value. If LLR is used, the replacement is equivalent to setting the likelihood to zero. This simple technique can assist in achieving appropriate FEC decoding that suppresses arbitrary adjacently received signals. Since all functions other than the FEC metric masking are the same as in a conventional OFDM receiver, implementation is easy. Note that similar processing could be done by passing the signals through a filter that suppresses interference signals.

4. Evaluation

We evaluated the reception performance and

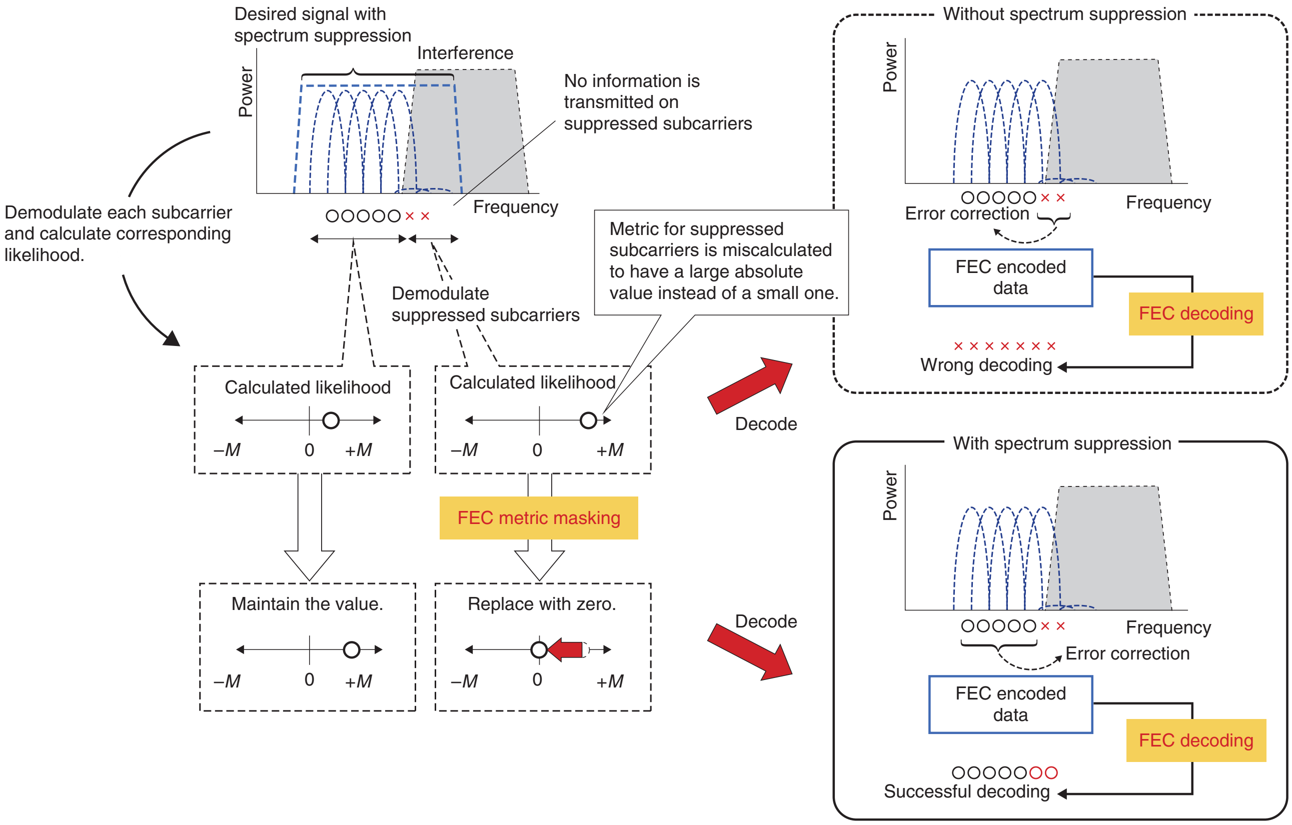


Fig. 5. Appropriate error correction performed by spectrum suppression at the receiver.

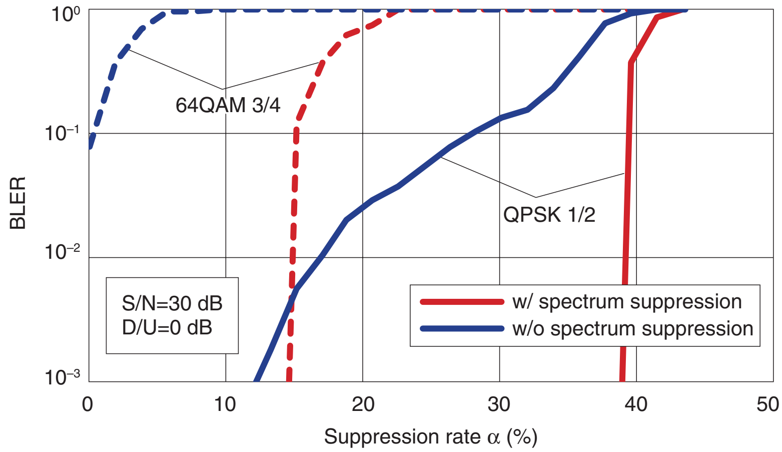
Table 1. Simulation parameters.

1st modulation	QPSK, 16QAM, 64QAM (adaptive)
2nd modulation	OFDM (851 subcarriers)
Subcarrier spacing	10.94 kHz
FEC coding	Convolutional turbo coding
FEC rate	1/2, 3/4 (adaptive)

frequency utilization efficiency by computer simulation. Major simulation parameters are listed in **Table 1**. They all conform to Mobile WiMAX [3].

The block error rate (BLER) versus suppression rate α is shown in **Fig. 6**. FEC metric masking on the suppressed subcarriers greatly improved the performance during spectrum suppression adaptation. For an assumed target BLER of 10^{-1}, our scheme achieved a maximum tolerable suppression rate of 38% for QPSK 1/2 and 15% for 64QAM 3/4 compared with 27% for QPSK and 0% for 64QAM 3/4 without this scheme (QPSK: quadrature phase shift keying; 64QAM: 64-state quadrature amplitude modulation; 1/2, 3/4: coding rates, i.e., the number of bits per symbol). This is a remarkable increase in simultaneous frequency sharing.

The frequency utilization efficiency versus suppression rate α is shown in **Fig. 7**. The frequency utilization efficiency is defined as the transmission bit rate that can be achieved within the total bandwidth (f'_{all}) occupied by two signals. Note that the suppression rates of the two signals are the same for simplicity ($\alpha = \alpha_1 = \alpha_2$). Without spectrum suppression, the frequency utilization efficiency is greatly degraded, especially when α is more than 15%. This is because the likelihood for suppressed subcarriers is miscalculated, as mentioned above. On the other hand, with our spectrum suppression technique, the frequency utilization efficiency increases as α increases. Note that the staircase pattern of the performance line is caused by changes in modulation order or FEC coding rate for adaptive modulation and coding. When α is less than 15%, our scheme with



S/N: signal-to-noise ratio
D/U: desired-to-undesired ratio

Fig. 6. BLER characteristics.

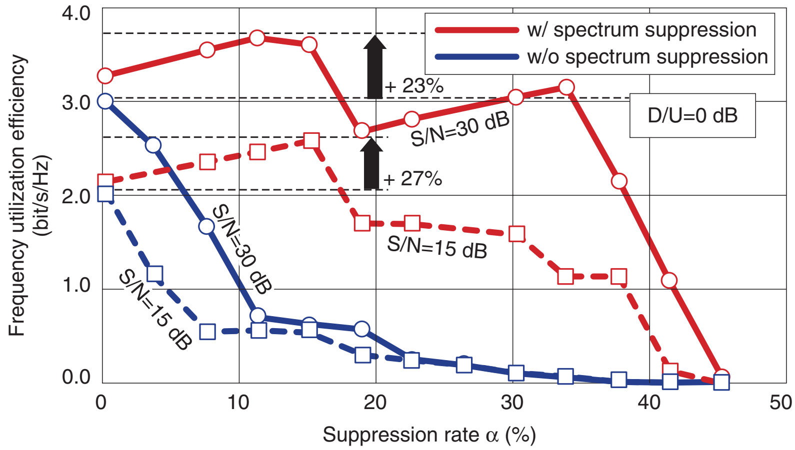


Fig. 7. Frequency utilization efficiency.

spectrum suppression can achieve higher frequency utilization efficiency than the conventional scheme, which does not share frequency resources at all (α=0%). The maximum improvement ratio is more than 20%. Note that the performance difference when α=0% is also due to spectrum suppression, which can suppress the sidelobe of the adjacent signal.

5. Conclusion

This article explained our spectrum suppressed transmission scheme, which increases frequency utilization efficiency. It also introduced FEC metric masking, which can improve reception performance. Computer simulation verified that using these two techniques can raise frequency utilization efficiency to about 20%.

References

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