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(Data Compression Algorithm for Efficient Data Transmission in Digital Optical Repeaters)

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Abstract

Today, the demand for high-speed data communication and mobile communication has exploded. Thus, there is a growing need for optical communication systems that convert large volumes of data to optical signals and that accommodate and transmit the signals across long distances. Digital optical communication with these characteristics consists of a master unit (MU) and a slave unit (SU). However, the digital optical units that are currently commercialized or being developed transmit data without compression. Thus, digital optical communication using these units is restricted by the quantity of optical frames when adding diversity or operating with various combinations of CDMA, WCDMA, WiBro, GSM, LTE, and other mobile communication technologies. This paper suggests the application of a data compression algorithm to a digital signal processor (DSP) chip as a field programmable gate array (FPGA) and a complex programmable logic device (CPLD) of a digital optical unit to add separate optical waves or to transmit complex data without specific changes in design of the optical frame.

Keywords Data Compression, Field Programmable Gate Array, Digital Optical Repeater, Diversity Channel

Ⅰ. INTRODUCTION

As an engineering technology to solve the problem of blind spots and to enhance network coverage, repeaters play an important role in present CDMA, W-CDMA, WiBro, GSM, and LTE mobile communication business networks[1~2].

The main components of a repeater are uplink and downlink transceivers, a DSP module, an optical module, a management module, and a power supply module. For different applications, there are different types of repeaters such as RF wideband repeaters, fiber optic repeaters, digital optical repeaters, and band selective repeaters[3]. Among these repeaters, the digital optical repeater gives the highest performance for its price and is currently the most popular. The main specifications for evaluating a repeater are its intelligence (i.e., local and remote monitor), adjacent channel power ratio (ACPR), noise figure, and reliability.

However, problems occur when repeaters are used for transmission optimization. Unlike the past, when data transmission rates were low, demand for high-speed data communications and mobile communications has now exploded. Thus, there is a growing need for optical communications that convert a large volume of data to optical signals, accommodate the signals, and transmit them over a long distance. However, these requirements are restricted by the quantity of optical frames when adding diversity or operating with various combinations of CDMA, WCDMA, WiBro, GSM, LTE, and other mobile communication technologies.

Ⅱ. Related Work

Digital optical units that are currently commercialized transmit data as shown in Figure 1.

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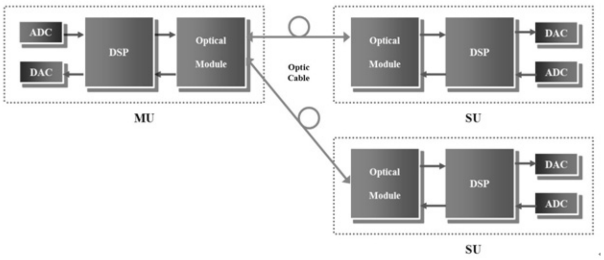

Fig. 1. Data transmission of digital optical units.

The transmission rate of optical frame structures of digital optical units that are currently in use observes a 3 Gb/s standard. Moreover, the transmission rate from digital optical units in use or under development to optical modules is as follows:

$$14 \text{ bits} \times 100 \text{ MHz} = 1.4 \text{ Gb/s} \quad (1)$$

Thus, there are up to two types of signals transmitted with a standard frame. When operating with various combinations of CDMA, WCDMA, WiBro, GSM, LTE, and other technologies or adding diversity, the sampling frequency can be adjusted to be low, but not under a certain level since aliasing problems may occur up to the sampling frequency. However, the number of bits can be adjusted if a compression algorithm is applied in this structure. In this way, it is possible for the system to operate more efficiently.

First, a compression algorithm is introduced. Then, test results are compared and analyzed between the existing method and the method using the compression algorithm.

Ⅲ. Data Compression Scheme

The compression algorithm must convert 14-bit binary data in fixed-point type to 10-bit binary data in floating-point type. Fixed binary data has a total of 10 bits: 1 encoding bit, 3 exponent bits, and 6 mantissa bits. Of course, it is possible to adjust the exponent and mantissa parts for more compression, but this may cause weak signal strength. Therefore, the number of bits was kept at 10 in tests. Table 1 shows 14-bit sampling data.

Table 1. Sampled Data (14 bits).

Sampling frequency	Sampling data
1/Fs	1111 ··· 0011
2/Fs	0000 ··· 1111
3/Fs	1111 ··· 0100
4/Fs	1111 ··· 0011
5/Fs	0000 ··· 1100
6/Fs	1111 ··· 0100
7/Fs	0000 ··· 1101
8/Fs	0000 ··· 1100

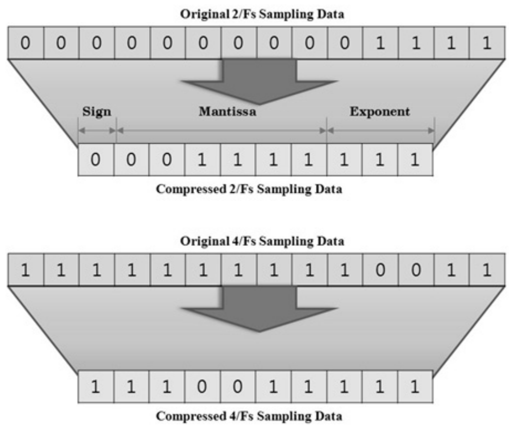

Fig. 2. Data compression procedure.

Figure 2 shows the compression process on 2/Fs and 4/Fs with 14-bit sampling data as mentioned above. The algorithm applied for data compression is as follows: first, compare the most significant bit (MSB) of the existing sampled data and the following bit; if they are equal, save the rest of the bits except the MSB, add "0" to the following least significant bit (LSB), and add "1" to the exponent value; if the value is different, save the existing sampled data as it is. The number of exponent bits was fixed at 3, as mentioned above. Thus, the algorithm was organized up to "111." Here, sampled data indicate "1" or "0," repeatedly. Thus, even though this algorithm compresses data, data loss may appear to a small degree compared to the signal-to-noise ratio (SNR). In the compression process, the MSB in the compressed data becomes the 14-bit MSB and the data of the mantissa including the MSB enters the

Table 2. Pseudo-Code for the Overall Signal Processes (In MU).

```
- The algorithm compares the MSB value with the next
bit value of
  the received sampled data
   while (from n-1toe+1)
    If the MSB and the next bit value are equal
        All bit values except the next bit are stored by
 adding "0"  to the
     assigned array space of nbits
        The value of "0" and "1" are stored in the
 assigned array space of
     e bits
    Else
     All bit values including the next bit are stored in the
assigned
      array space of nbits
                  End if
                End while
   The upper
mbitsofthenbitsarestoredtothenbits'floating-point
   value
   The n bits' floating-point value is transmitted to the
 optical module
- The algorithm checks the MSB value of the received
floating data
   If the MSB value equals "0"
    The value from e+mbitstoebitsisstoredwithzerosplacedin
 n-
    m-2 bits in the assigned array space of nbits
   Else
     The value from
 e+mbitstoebitsisstoredwithonesplacedin  n-
    m-2 bits in the assigned array space of nbits
               End if
   The lower ebitsofthefloatingdataarestoredtotheassigned
   array space of ebits
    while (from n-1toe+1)
     If the assigned array value equals "0"
         The value of n bits is stored in the next
 assigned array space
      The value of the lower
ebitsisstoredinthenextassignedarray
      space
     Else
         The value of
 n-1bitsexcepttheLSBbitisstoredbyaddingthe
     MSB to the next assigned array space
      The value of the lower
ebitsdecreasesbyone,thenthevalueis
      stored to the next assigned array space
                   End if
              End while
```

recovery data space at the same time until the estimated exponent value becomes "0."

Original data is restored via a restoration process. Sampled data, as mentioned above, can be restored to the original data if sampled values are rather small, but it is difficult to restore data with large values. Again, in this case, some data with low values are not completely restored to the original state because this does not greatly affect the adjacent channel leakage ratio (ACLR) or error vector magnitude (EVM) in communication.

Table 2 shows the overall digital processes as pseudo-code. Letter n is the number of bits in the floating-point data in the proposed algorithm. Letter m is the number of bits used for the mantissa of the floating-point data. Letter e is the number of bits used for the exponent of the floating-point data. The 14bit sare the sampled number of bits of the fixed-pointd ata. Further, they are real transceiver data connected to the RF front end in our implemented system.

Ⅳ. Analysis and Experiment Results

As shown in Figure 3, a test environment was established for actual tests of the applied compression algorithm.

The settings of spectrum analyzer are shown in Table 3.

Here, the sampling frequency (Fs) is 100 MSPS and the digital optical module operated at 3 Gbps broadband. A WCDMA signal at -10 dBm was used for the MU ADC by a vector signal generator. Under these conditions, the DAC was measured by a

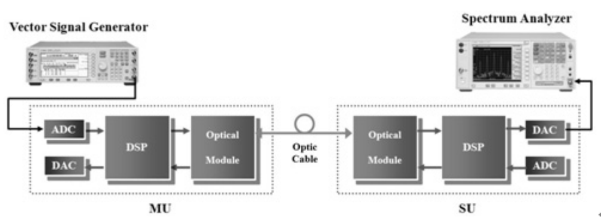

Fig. 3. Test environment.

Table 3. Setting parameters of the spectrum analyzer.

Parameter	Value
Test Mode	ACPR
Center Frequency	62.5 MHz
Span	25 MHz
Ref level	-20 dBm
Sale/DIV	10 dB/DIV
Attenuator	0 dB
RBW	30 kHz
VBW	3 kHz

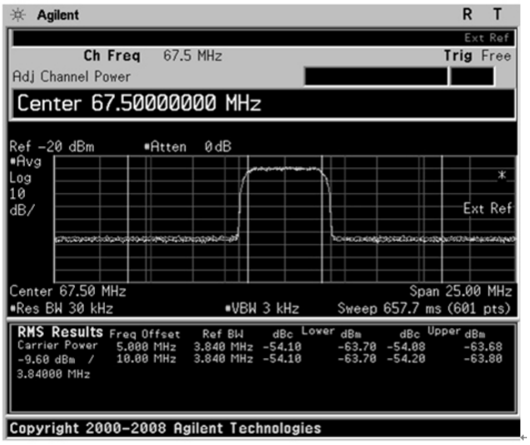

Fig. 4. ACLR.

spectrum analyzer after optical loopback. Figure 4 indicates ACLR measured by the spectrum analyzer, and Figure 5 shows EVM.

Figure 4 indicates that the ACLR is impaired by approximately 2 dB when compared to existing signals. As mentioned above, this is a very slight impairment compared to the SNR and does not deviate from the specifications of the whole system. In addition, in Figure 5, the EVM shows no significant difference when compared to the existing value.

As shown in Table 4, if the data are converted to floating-point type, data are shown compressed from 14 bits to 10 bits.

The transmission method used to compress data from fixed-point to floating-point shows the same effects in both of the following cases: from MU ADC to SU DAC and from SU ADC to MU DAC.

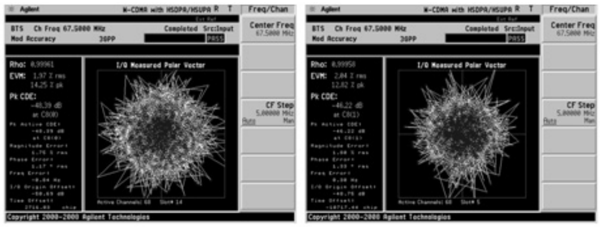

Fig. 5. (a) EVM of original data,
(b) EVM of compressed data

Table 4. Compressed Data.

Sampling frequency	Sampled data
1/Fs	1110011111
2/Fs	0001111111
3/Fs	1110100111
4/Fs	1110011111
5/Fs	0001100111
6/Fs	1110100111
7/Fs	0001101111
8/Fs	0001100111

Moreover, even though the power input of the ADC increases or decreases, the range of ACLR change is low when compared to that before compression. This indicates that even though the values of the sampled data (14-bit) increase or decrease, the type of the compressed data (10-bit) is not affected because it has almost the same level. This is a characteristic of the applied compression algorithm.

Now, let us examine the considerations for data compression. To compress data, an encoding unit must be added. Also, a general sum or multiplication is not possible for compressed data. Thus, a decoding process is necessary if there is a DSP process in the middle of transmission.

Received data as fixed-point type is converted from the ADC of the DSP and transmitted. Inversely, the data received as floating-point type from the optical receiver is converted to fixed-point type and transmitted to the DAC.

If a resource or delay shows that many encoding and decoding units are required, the target device is changed in the DSP. Thus, cost may increase. Moreover, delay in a communication system is one of the most important specifications. Thus, it is necessary to select scrambling that has low delay. Here, since encoding and decoding are very simple DSP processes, there is no problem with resources or delay. Thus, a compression algorithm with floating-point conversion type is considered applicable for the whole communication system.

Ⅴ. Conclusion

This paper suggested a data compression method that is required when adding diversity or operating various combinations of CDMA, WCDMA, WiBro, GSM, and LTE. This method can be applied to digital optical equipment installed previously since application is possible with only a modification of the firmware of the DSP unit without any addition of optical waves or changes in the optical frame. Moreover, this compression method is a very simple DSP process, so there are no problems with resources or delays. Even though the power input to the ADC is low or high, a stable SNR can be secured because of the small range of change in the ACLR. This method does not show impairment of EVM, which is also quite important.

References

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