Performance analysis on three-layered division multiplexing transmission

Soon-Young Kwon, Ho Jae Kim, and Hyoung-Nam Kim
Dept. of Electronics Engineering
Pusan National University
Busan, Republic of Korea
hnkim@pusan.ac.kr

JaeHwui Bae, YoungSu Kim, and Namho Hur
Electronics and Telecommunications Research Institute
Daejeon, Republic of Korea
jhbae@etri.re.kr

Abstract— **Layered division multiplexing (LDM) was introduced into the physical layer of Advanced Television Systems Committee (ATSC) 3.0 broadcasting system, where two-layer LDM is used as a standard. The LDM system provides more frequency efficiency than the existing single layer system. To increase the efficiency of LDM, we consider a three-layer system by adding more blocks to the ATSC 3.0 system. Through simulation, the bit error rate (BER) performance for each layer of the three-layer LDM is analyzed in various situations. We compare the BER performance for each layer of the three-layer LDM with injection levels in additive white Gaussian noise (AWGN).**

Keywords—Layered division multiplexing (LDM); digital terrestrial broadcasting; ATSC 3.0

I. Introduction

In the field of broadcasting and communication, as the demands for high quality contents increase, various researches have been carried out in order to increase the radio frequency (RF) spectral efficiency [1-2]. In recent years, researches on layered division multiplexing (LDM) system, one of studies for increasing spectral efficiency, have been actively conducted [3]. An extension of Cloud Transmission system [4], the LDM is a frequency overlay technique for transmitting several data streams on one RF channel. The LDM system provides higher transmission efficiency than the time division multiplexing (TDM) or frequency division multiplexing (FDM) system. In the Advanced Television Systems Committee 3.0 (ATSC 3.0) [5], the next generation terrestrial broadcasting standard, a two-layer LDM system was adopted as a physical layer. Figure 1 shows the spectrum of two-layer LDM. The power of the lower layer (LL) is smaller than the power of the upper layer (UL) by the injection level. As an example of the use of the two-layer LDM, the upper layer provides a high definition (HD) mobile service using a robust modulation scheme. The lower layer provides the ultra high definition (UHD) service in fixed reception using dense modulations [3].

Currently, studies on the two-layer LDM system have been actively conducted but it is expected that additional layers are needed to provide various services at a limited frequency. To go over the possibility of the use of additional layers, we consider a three-layer LDM system and simulate it in additive white Gaussian noise (AWGN) channel and analyze the bit-error rate (BER) performance according to SNR by changing the injection level.

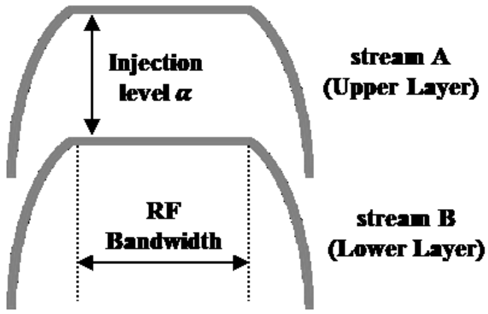

Fig. 1. Spectrum of two-layer LDM signal

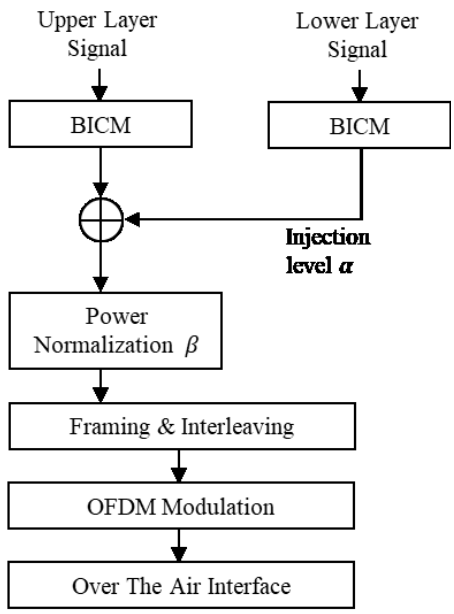

Fig. 2. Transmission block diagram of a two-layer LDM system

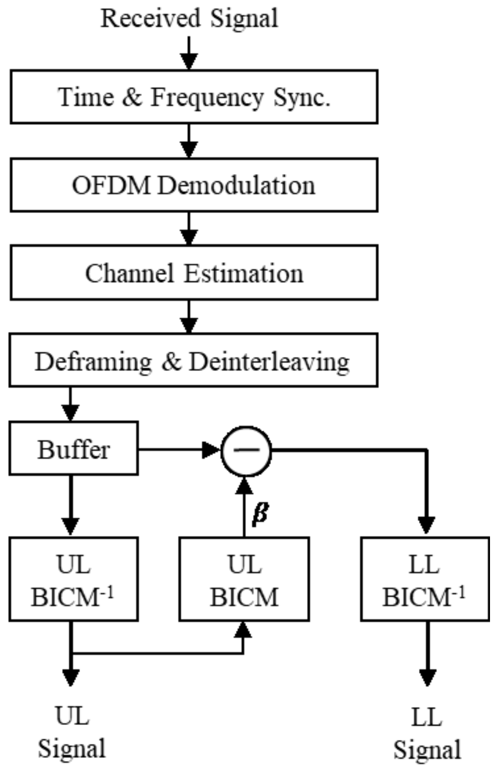

Fig. 3. Reception block diagram of a two-layer LDM system.

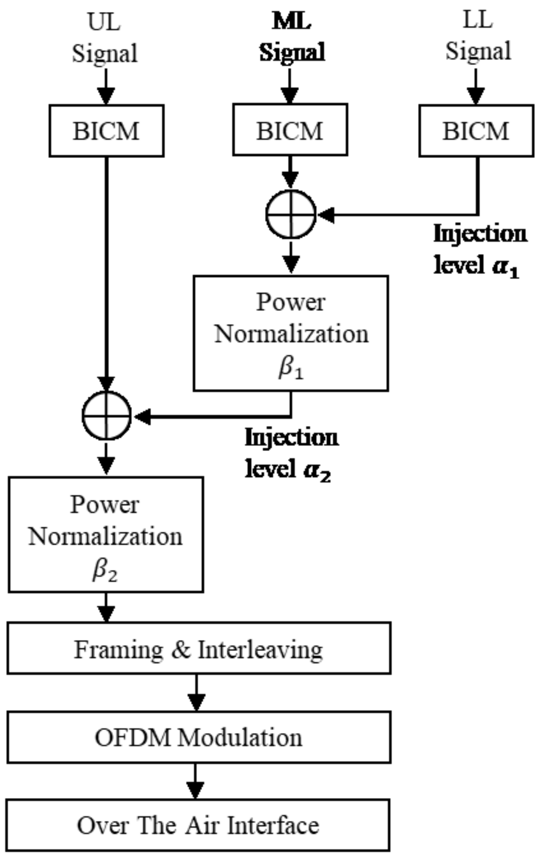

Fig. 4. Transmission block diagram of a three-layer LDM system

II. LDM System

A. *Two-layer LDM* [3]

The LDM system transmits multiple signals in one RF channel using different power levels, error correction techniques, and modulation schemes. In the case of a two-layer LDM, a signal with a higher power level is called an upper layer (UL), and a signal with a lower power level is called a lower layer (LL).The UL signal uses the same or more robust modulation scheme and error correction techniques than the LL signal. For example, if UL is 4QAM, LL can be 16QAM or high order modulation. In general, UL signal using a robust modulation are targeted at mobile devices, and LL signal using a high order modulation is targeted for fixed reception devices.

Figure 2 shows the transmission block diagram of the 2-layer LDM system. As shown in figure 2, the two signals are combined into a single signal after each BICM is applied. The transmitted signal can be expressed as follows:

$$s(t) = \beta(x_{UL}(t) + \alpha x_{LL}(t)), \quad (1)$$

where s is transmission signal, x_{UL} and x_{LL} are UL signal and LL signal, respectively. β is factor of the power normalization.

Assuming that the channel is not affected and is free of noise, the received signal is equal to $s(t)$. First, in order to demodulate the UL signal, the receiver stores $s(t)$ in a buffer and demodulates $s(t)$ as shown in figure 3. Then, in order to demodulate the LL signal, the demodulated UL signal is remodulated and multiplied by the power normalization factor β, and them removed from the buffer signal. This signal can be expressed as follows:

$$s_{LL}(t) = s(t) - \beta x_{UL}(t) = \beta\alpha x_{LL}(t). \quad (2)$$

Finally, the LL signal can be obtained by demodulating the signal $s_{LL}(t)$.

B. *Three-layer LDM*

The three-layer LDM system is an extended concept of two-layer LDM system. In the case of three-layer, each layer is defined as an upper layer, a middle layer (ML) and a lower layer in order from the highest power level. The process of three-layer LDM modulation is shown in figure 4. The modulation process of the three-layer LDM is similar to the two-layer LDM. First, the LL signal and ML signal are superimposed in the same process as the two-layer LDM. This modulated signal can be expressed as follows:

$$s_{LL+ML}(t) = \beta_1(x_{ML}(t) + \alpha_1 x_{LL}(t)), \quad (3)$$

where x_{ML} is middle layer signal, $s_{LL+ML}(t)$ is a signal in which x_{ML} and x_{LL} are superimposed, α_1 is injection level between x_{ML} and x_{LL}, β_1 is normalization factor of $s_{LL+ML}(t)$.

In the same way, $s_{LL+ML}(t)$ and UL signal are superimposed. This superimposed signal can be expressed as follows:

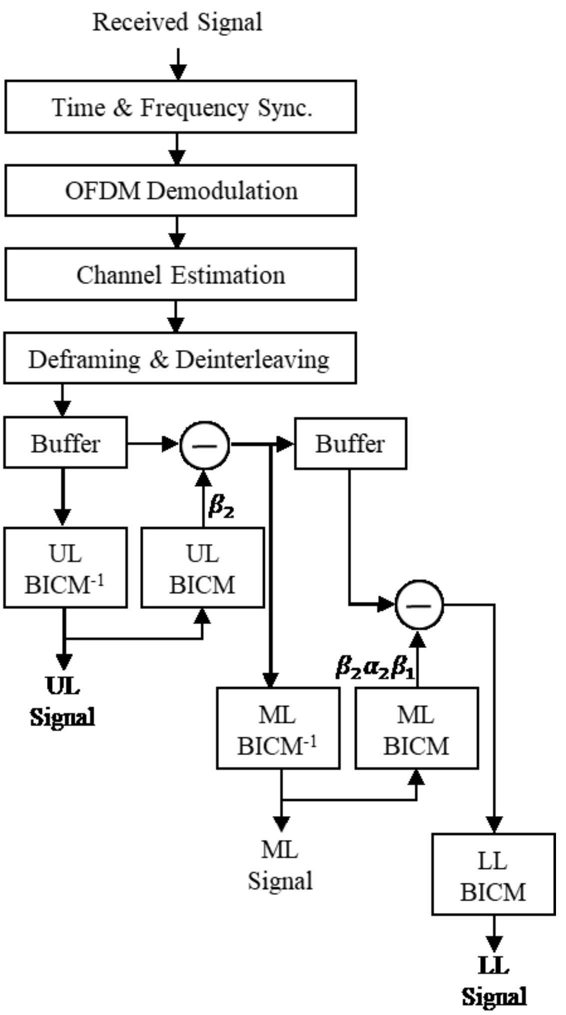

Fig. 5. Reception block diagram of a three-layer LDM system

$$s(t) = \beta_2\big(x_{UL}(t) + \alpha_2 s_{LL+ML}(t)\big), \quad (4)$$

where $s(t)$ is transmission signal, α_2 is injection level between x_{UL} and $s_{LL+ML}(t)$, β_2 is normalization factor of $s(t)$.

After the three-layer LDM signal $s(t)$ is generated, the signal is transmitted over the air. If the transmitted signal is applied to an AWGN channel, the received signal $r(t)$ is as follows:

$$r(t) = \beta_2(x_{UL}(t) + \alpha_2\beta_1(x_{ML}(t) + \alpha_1 x_{LL}(t))) + n(t), \quad (5)$$

where $n(t)$ is noise with a Gaussian distribution..

The demodulation process of the three-layer LDM is similar to the two-layer LDM. The process of three-layer LDM demodulation is shown in figure 5. First, in order to demodulate the UL signal, the receiver stores $r(t)$ in a first buffer and demodulates $r(t)$. The demodulated UL signal is remodulated and multiplied by the power normalization factor β_2, and them removed from the first buffer signal. This signal can be expressed as follows:

TABLE 1 SIMULATION PARAMETERS

	QAM Mode	FFT Size	Guard Interval	Bandwidth
UL	4	16k	1/8(2k)	8MHz
ML	4			
LL	64			

$$r_{ML+LL}(t) = \beta_2\alpha_2\beta_1 x_{ML}(t) + \beta_2\alpha_2\beta_1\alpha_1 x_{LL}(t) + n(t). \quad (6)$$

Next, in order to demodulate the ML signal, the same process as that for demodulating the receiver stores $r_{ML+LL}(t)$ in a second buffer and demodulates $r_{ML+LL}(t)$. Next, in order to demodulate the LL signal, the demodulated ML signal is remodulated and multiplied by $\beta_2\alpha_2\beta_1$, and them removed from the second buffer signal. This signal can be expressed as follows:

$$r_{LL}(t) = \beta_2\alpha_2\beta_1\alpha_1 x_{LL}(t) + n(t). \quad (7)$$

Finally, the LL signal can be obtained by demodulating the signal $r_{LL}(t)$.

III. Simulation Result

We analyzed the BER performance for each layer of the three-layer LDM in an AWGN channel. The common parameters used in the simulation are summarized in Table 1. In figure 6 and figure 7, the solid lines represent $\alpha_1 = 3$ dB, $\alpha_2 = 4$ dB, the dotted lines is $\alpha_1 = 2$ dB, $\alpha_2 = 3$ dB.

Figure 6 shows the simulation result of BER for each layer according to the injection levels. The code rates of UL, ML, and LL are 1/3, 1/2, and 2/3, respectively. For the desirable BER of 10^{-6}, the required SNR of UL and ML decreased by 1.1 dB and 0.9 dB when the injection level increases. On the other hand, the required SNR of LL increased by 1.4 dB despite the increase in injection level.

Fig. 7 shows the simulation results for different code rates from that of Fig. 6. The code rate of each layer slightly decreased to 1/4, 1/3, and 3/5. For the BER of 10^{-6}, the required SNR of UL and ML decreased by 0.8 dB and 0.1 dB when the injection level increases. On the other hand, the required SNR of LL also increased by 1.3 dB despite the increase in injection level.

When the code rate of each layer was reduced, the required SNR of each layer was also reduced. The required SNR of UL and LL was reduced by 1.7 dB, 0.8 dB, and the required SNR of ML is greatly reduced by about 4.3 dB. Compared to ML in Figs. 6 and 7, the required SNR was not substantially reduced at low code rate despite the increase in injection level. However, at high code rate, the required SNR is greatly reduced.

IV. Conclusion

We extended the layer of LDM from two layers to three layers to further increase the frequency efficiency and compared the BER performance for each layer of three-layer LDM according to code rates and injection levels. Simulation results show that the lower the code rate becomes, the better the performances of all layers are improved, especially in ML. When the code rate is fixed, the required SNRs of UL and ML decrease and that of LL increases when the injection level increases. In the case of ML, the required SNR decreases more at the lower code rate than at the higher code rate.

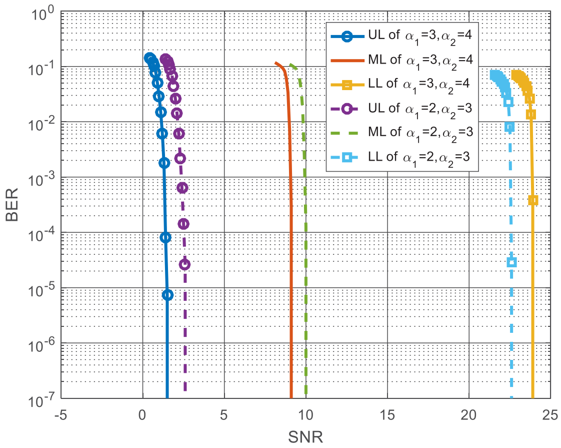

Fig. 6. BER performance of three-layer LDM in code rate of each layer (UL : 1/3, ML : 1/2, LL : 2/3)

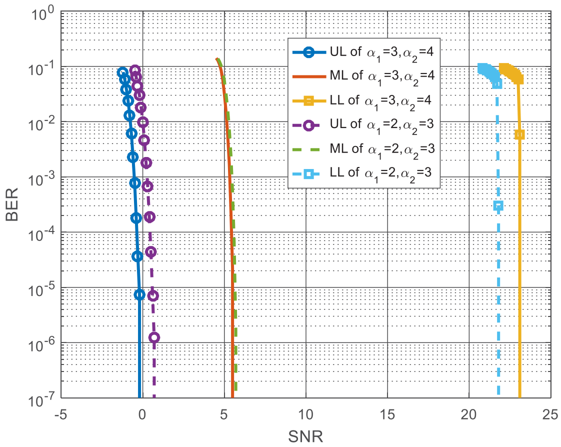

Fig. 7. BER performance of three-layer LDM in code rate of each layer (UL : 1/4, ML : 1/3, LL : 3/5)

ACKNOWLEDGMENT

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REFERENCES

[1] E. Stare, J.J. Gimenez, P. Klenner, "WIB: a new system concept for digital terrestrial television(DTT)," IBC 2016 conference.

[2] Erik G. Larsson, Ove Edfors, Fredrik Tufvesson, Tomas L. Marzetta, "Massive MIMO for next generation wireless systems," IEEE Communications Magazine, vol. 52, no. 2, pp. 186-195, February 2014.

[3] Liang Zhang, Wei Li, Yiyan Wu, Xianbin Wang, Sung-Ik Park, Heung Mook Kim, Jae-Young Lee, Pablo Angueira, Jon Montalban, "Layered-Division-Multiplexing: Theory and Practice," IEEE Transactions on Broadcasting, vol. 62, no.1, pp. 216-232, March 2016.

[4] Yiyan Wu, Bo Rong, Khalil Salehian, Gilles Gagnon, "Cloud Transmission: A New Spectrum-Reuse Friendly Digital Terrestrial Broadcasting Transmission System," IEEE Transactions on Broadcasting, vol. 58, no. 3, pp. 329-337, September 2012.

[5] ATSC Standard: Physical Layer Protocol (A/322), Advanced Television Systems Committee, Jun 2017.