A Study of EVM Degradation in 5G Signal Digital Modulation Due to PLL in-band Phase Noise

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***Abstract*— This paper presents the effect of in-band phase noise of PLL(Phase Locked Loop) used as LO signals in 5G communication on EVM based on measurement. Transceiver for 5G NR communication proposed in this paper consists of up/down mixer and T/RX transmitter and PLL. PLL is based on fractional, EVM is measured bandwidth 80 MHz at 27 GHz, a subcarrier frequency of 120 kHz, and 64 QAM modulation signal. PLL phase noise degradation analysis provided by each block and other characteristics of PLL were fixed, and the charge pump current and phase frequency detector delay were changed to measure EVM degradation according to changes in in-band phase noise.**

Keywords —EVM, Phase Noise, 5G NR

I. INTRODUCTION

Recently, advances make the 28 GHz band particularly interesting for 5G mobile standardization[1-2]. PLL providing the LO signal in the transceiver block is an important block that determines the quality of communication. It will have a great influence on the modulation/demodulation of communication. In this paper, the effect of measurement-based PLL in-band noise on 5G NR communication EVM was studied. Parameters such as the LO frequency and the REF frequency and the corresponding frequency division ratio N are determined by the 5G communication standard. Accordingly, in this paper, EVM degradation according to in-band phase noise change according to the change in charge pump current and PFD delay of PLL was measured.

II. EVM DEGRADATION DUE TO PLL IN-BAND PHASE NOISE

Figure 1. is a transceiver block diagram. The transceiver consists of Up/Down mixer, T/RX chain, PLL(Phase Locked Loop), and the PLL consists of a REF oscillator, PFD(Phase Frequency Detector), CP(Charge pump), VCO(Voltage Controlled Oscillator), LF(Loop Filter), MMD(Multi Modulus Divider) and DSM(Delta Sigma Modulator).

$$\sigma_{\Delta PLL} = \sqrt{\eta M K_{clk} K_{VCO} \sqrt{1 + \frac{1}{4\zeta^2}}} \qquad (1)$$

$$\sigma^2{}_{\Delta\Phi in} = \eta N^2 K^2{}_{clk} \left(\frac{R_1 I_p K_{VCO}}{4\pi N} + \frac{1}{2R_1 C_1}\right) \qquad (2)$$

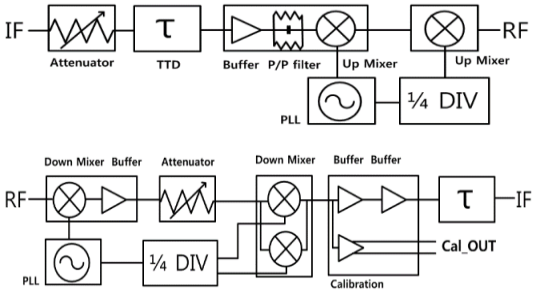

FIG1. BLCOK DIAGRAM OF 5G TRANSCEIVER

Equation 1,2 presents contribution of each block of PLL to the phase noise variance at the output of the PLL[3-5]. In accordance with Equations 1 and 2, in PLL total phase noise, VCO noise is HPF(High Pass Filter) characteristics and REF oscillator, PFD, CP and etc. noise are LPF(Low Pass Filter) characteristics. The 27 GHz transceiver was designed for 5G communication. The mixer LO signal is 20 GHz, the IF signal is 2 GHz, and the REF oscillator is 100 MHz. Thus, N is set to 200, and other parameters that can affect in-band phase noise are typically the current of charge pump(I_p) and the delay to eliminate the dead zone of PFD.

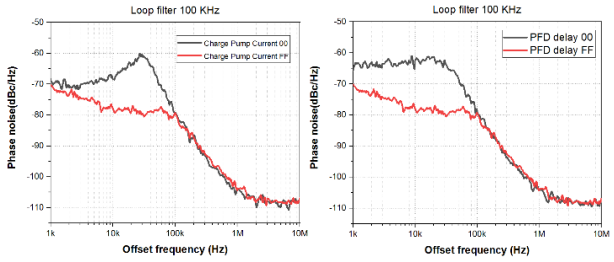

FIG2. IN-BAND PHASE NOISE ACCORDING TO CHARGE PUMP CURRENT & PFD DELAY CHANGE

Fig. 2 illustrates the in-band phase noise measurement result when the R, C values, and the like of the loop filter are fixed and the charge pump current and the delay of PFD are adjusted. The loop filter bandwidth is 100 kHz.

III. Measurement of EVM of Transceiver

Figure 3 shows the EVM measurement results by adjusting the charge pump current. According to the 5G communication standard, it was measured using a 64 QAM signal at a signal bandwidth of 80 MHz at a carrier frequency of 27 GHz and a subcarrier spacing of 120 kHz. When the charge pump current is 1 mA, the TX signal EVM is 8.6%, and when the current is 2.7 mA, the EVM is 5.9%.

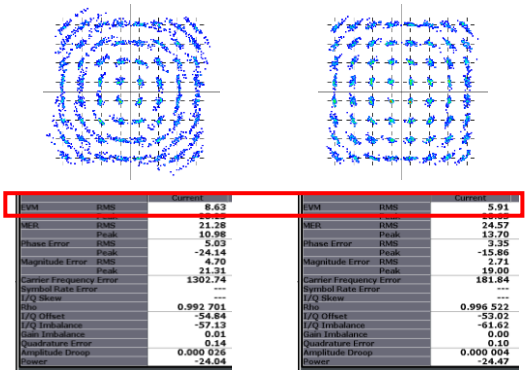

FIG3. EVM ACCORDING TO CHARGE PUMP CURRENT CHANGE

Figure 4 shows the EVM measurement results by adjusting delay of the PFD. The signal used for the measurement is the same. When delay of PFD is 0 usec, the TX signal EVM is 8.9%, and when the delay is 200 usec, the EVM is 5.9%.

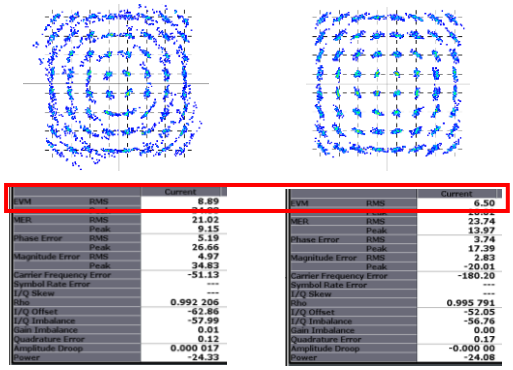

FIG4. EVM ACCORDING TO PFD DELAY CHANGE

IV. Conclusion

Since other parameters of PLL (typically output frequency, REF OSC., frequency, frequency division ratio, and Kvco) that provide the LO signal of the transceiver are fixed, the EVM of the communication signal can be optimized by optimizing charge pump current and PFD delay.

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