

Transmission Signal Quality Comparison of SCM and OFDM according to the Phase Noise Characteristics of the Local Oscillator

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Abstract—This paper examines the transmission signal quality differences between SCM (Single Carrier Modulation) method and OFDM (Orthogonal Frequency Division Multiplexing) method by analyzing how the phase noise characteristics of the local oscillator influences and by comparing the test results of EVM(Error Vector Magnitude) and ACP(Adjacent Channel Power) using vector signal generator , vector signal analyzer and simulation tool.

Keywords— SCM, Carrier modulation, Phase Noise, OFDM, Local Oscillator

I. INTRODUCTION

The development of wireless communication technology in recent years has been rapid as a variety of technologies were developed and commercialized to provide high-speed data communication, so that the people can use various services using high speed data communication at anytime and anywhere.

In case of using the existing SCM (Single Carrier Modulation) method, to achieve high-speed data rate increases with the speed of symbol-data rate, so that the ISI (Inter Symbol Interference) problem caused by multi-path becomes serious. One of the techniques to resolve ISI problem which is caused by a shortened symbol length is OFDM (Orthogonal Frequency Division Multiplexing). Since OFDM method divides a high speed data into several parallel low speed data and transmits those using orthogonal multi sub-carriers, it can significantly reduce ISI problem. On the other hand, OFDM method is very sensitive to frequency and phase errors involving transmitter-receiver design and verification due to the close spacing of sub-carriers ranging from a few kHz to dozens kHz. This paper presents transmission signal quality comparison between SCM and OFDM methods by comparing the impacts of phase noise characteristics of Local Oscillator using vector signal generator, vector signal analyzer and simulation tool.

II. RELATIONSHIP BETWEEN DIGITAL MODULATION TRANSMITTER'S STRUCTURE AND PHASE NOISE

A. Transmitter Structure

Figure 1 is a general single-carrier method transmission structure. It converts binary data to symbols and modulates, and thus the symbol rate increases due to the increase in data rate, which increases ISI (Inter Symbol Interference).

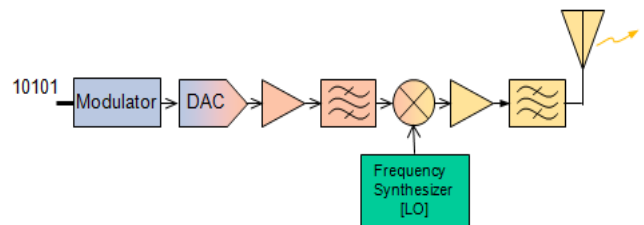


Figure 1. SCM (Single Carrier Modulation) method Transmitter Structure

Figure 2 is an OFDM method transmitter's structure. Since it transmits data using symbol-to-subcarrier mapping after converting binary data to symbols, the entire symbol rates are reduced to the number of sub-carriers, which can significantly reduce ISI (Inter Symbol Interference). Due to this advantage, this method is highly praised as an adequate high-speed data communication technique.

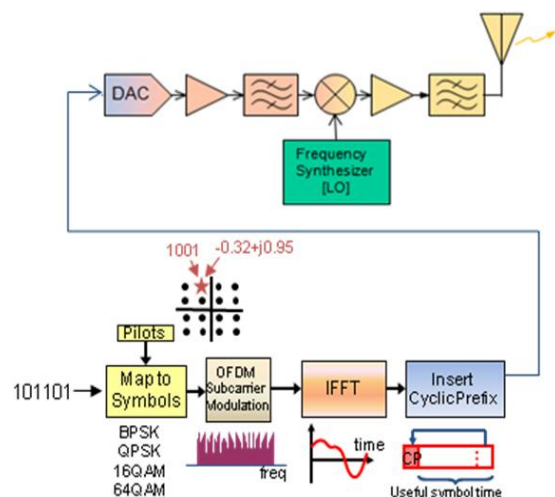


Figure 2. OFDM (Orthogonal Frequency Division Multiplexing) Method Transmitter's Structure

Both the methods employ local oscillators to get RF transmission frequency and local oscillator phase noise influences transmission signals in the process of up-conversion.

In the case of OFDM which closely spaces orthogonal sub-carriers, it can cause ICI (Inter Carrier Interference) even with a slight phase noise and thus OFDM requires special cautions for local oscillator phase noise characteristics. Due to phase noise, it has CPE (Common Phase Error) component influencing its own signal and ICI (Inter Carrier Interference) which has impact on adjacent sub-carrier signals, as indicated in the following Figure 1 and Figure 2

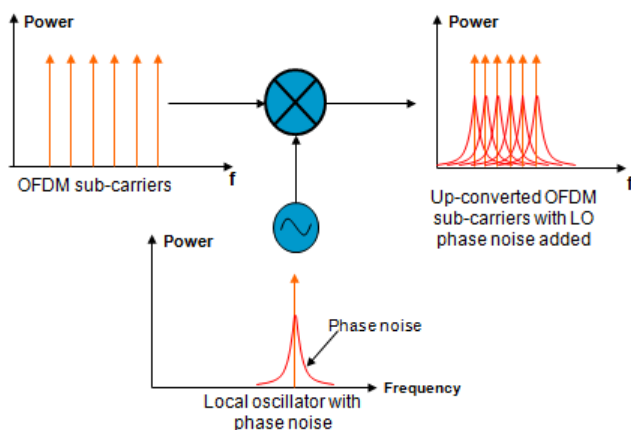


Figure 3. Distortion of OFDM Signals Due to Local Oscillator Phase Noise

A. Phase Noise

In the case of an ideal oscillator, there is no change in output level and frequency with the change of time, but in reality output level and phase are slightly changed. Figure 4 indicates comparison between ideal signal and real-world signal from time and frequency domains. It shows a distortion occurs in signals in the real environment due to the change in signal strength and phase value. Thus, random noise in the source causes dispersion in frequency domain and this dispersion is phase noise

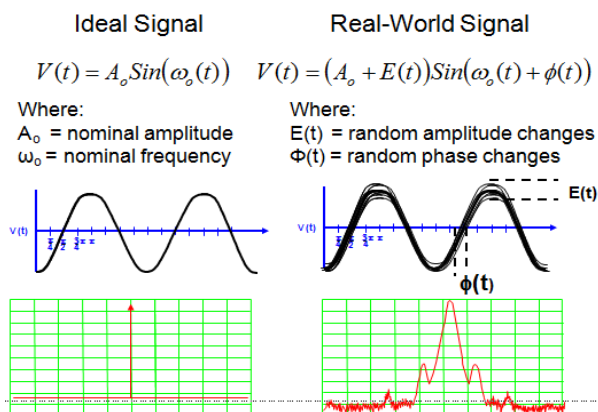


Figure 4. Signal characteristics of ideal signal and real-world signal

Phase noise is an indicator representing characteristics of oscillator that can generate identical frequency during a specific period, is generally described as SSB(Single sideband)

phase noise and is expressed as $L(f)$. $L(f)$ is described as the ratio of power density obtained in a specific frequency offset range for the entire power level of carrier signals.

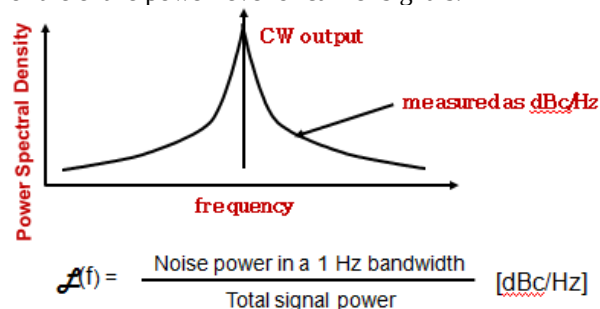


Figure 5. Expression of phase noise and measurement results

III.COMPARISON TEST ON TRANSMISSION SIGNAL QUALITY PERFORMANCE

A. Verification Background

The Figure.6 shows phase noise characteristic of Agilent MXG N5182B using PLL (Phase Locked Loop) Frequency Synthesizer. Generally, the elements affecting phase noise are Reference oscillator, Synthesizer, VCO (YIG oscillator) and system noise floor. The impact of Reference oscillator and VCO have characteristic of 20dB/decade slope. The starting point that VCO influences phase noise is determined by PLL loop Bandwidth.

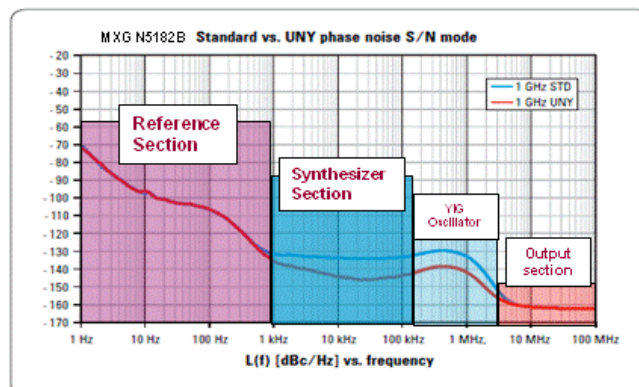


Figure 6. Phase noise characteristic of MXG N5182B

Influence of reference oscillator is decided by flicker noise (1/f) which is a unique noise possessed by active device. When PLL is locked, phase characteristics such as bandwidth noise floor appear according to the synthesizer noise characteristic within a certain range. This range is maintained until PLL loop bandwidth range but shows 20dB/decade slope characteristic according to VCO characteristic. At the end, it is affected by entire system noise characteristic.

For measurement, this paper conducted performance verification by adding phase noise impairment to Pedestal region among MXG's characteristics and WCDMA Downlink Test model 4 and LTE FDD Downlink ETM1.1 were used as a standard signal for SCM method and OFDM method, respectively, to set the carrier frequency 1GHz to 0dBm

TABLE 1. TEST SIGNAL USED FOR VERIFICATION

	Test Signal	Test Measurement	Active Channel & Modulation
OFDM	LTE FDD Downlink E-UTRA Test model 1.1 (E-TM1.1)	BS output power Unwanted emissions Occupied bandwidth ACLR Operating band unwanted emissions Transmitter spurious emissions Transmitter intermodulation RS absolute accuracy	P-SS,S-SS, PBCH, PCFICHP, PHICH, PDCCH, PDSCH, RS & Z-Chu, BPSK, QPSK
	3GPP release 8. TS 36.141 (V9.0.0)		
SCM	WCDMA FDD Downlink Test model 4	EVM measurement Total power dynamic range Frequency error	PCCHCH+SCH, Primary CPICH1 & QPSK
	3GPP release 99. TS 25.141(V3.9.0)		

B. Configuration and Method for Comparison Test

For verification, we generated test signal by using Agilent SystemVue as seen Figure 7 and conducted simulation by using Agilent 89601B VSA software.

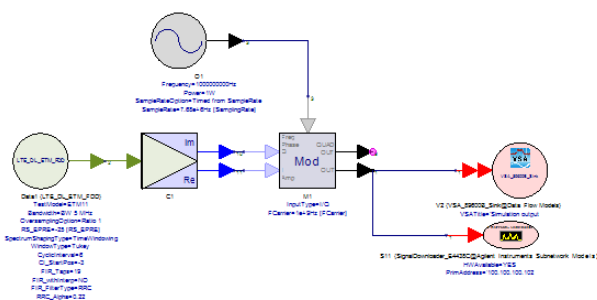


Figure 7. LTE Signal Generation Schematic using SystemVue

We conducted verification by downloading waveform generated by SystemVue to Agilent MXG vector signal generator to output 1GHz, 0dBm signal. In order to verify transmission signal, we used Agilent PXI Vector Signal Analyzer and Agilent 89601B VSA software to measure EVM

(Error Vector Magnitude) and ACP (Adjacent Channel Power) of signals.

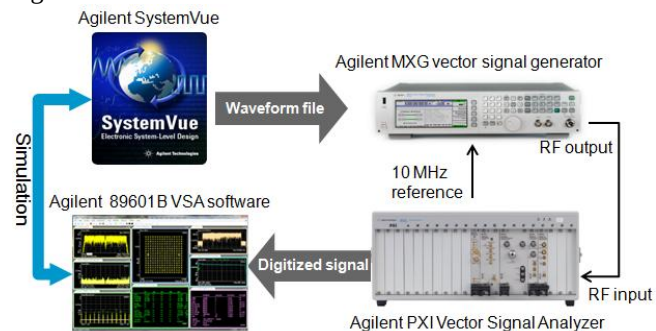


Figure 8. Measurment Composition for Verification

Figure 9 indicates LO Phase noise characteristic of vector signal generator. We changed offset frequency and offset level to test the performance of the pedestal region.

The start offset frequency range was set between 100Hz ~ 15 kHz and the stop was 1MHz and offset level varied from -120 to -90 dBc/Hz.

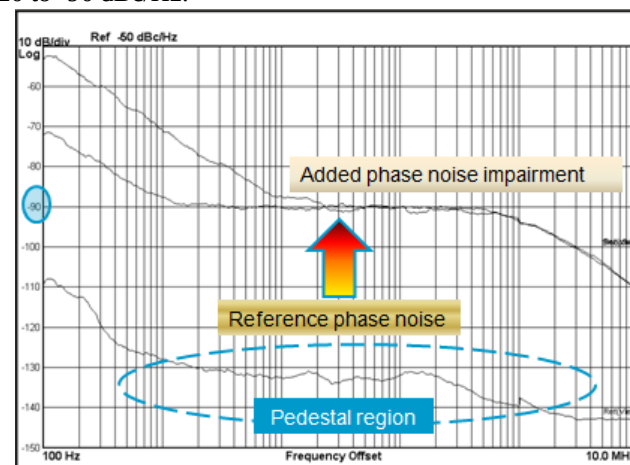


Figure 9. Own Phase Noise of MXG and Disorted Phase Noise

Given that each sub-carrier is arranged at the interval of 15 kHz in the case of LTE Downlink, we measured phase noise characteristics of signal generator by applying various offset levels at a spot 15 kHz away from the generator.

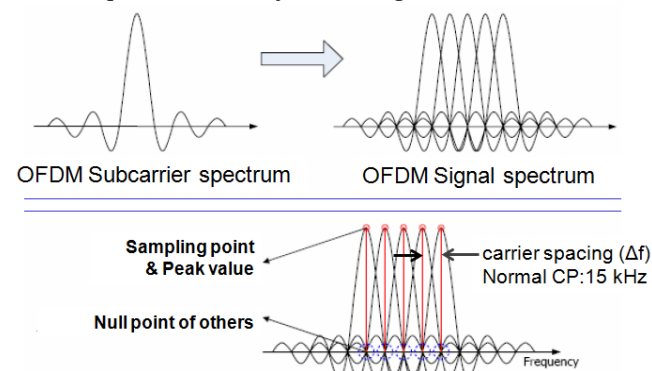


Figure 10. Spectrum and Carrier Spacing of OFDM Signal

C. Comparison Test Result

1) EVM Performance Comparison: In the case of WCDMA using a single carrier, change in EVM according to offset frequency at a certain offset level was 1dB. On the other hand, the change in EVM in the case of LTE using multiple sub-carriers was maximum 7.8 dB. In particular, offset frequency of phase noise of more than 5 kHz affected EVM performance of LTE. Also, the EVM change range according to offset level of phase noise was bigger in LTE than WCDMA.

TABLE 2. COMPARISON OF WCDMA VERSUS LTE EVM BASED ON PHASE NOISE

WCDMA TM-4 5MHz CF:1GHz, 0dBm					Difference with offset level
PN offset level [dBc/Hz]	-90	-100	-110	-120	
Start Freq[Hz]	EVM [dB]				
100	-26.94	-36.48	-41.50	-43.50	-16.56
1K	-26.74	-35.92	-41.47	-43.50	-16.76
5K	-26.94	-35.92	-41.45	-43.50	-16.46
10K	-26.74	-35.92	-41.43	-43.10	-16.36
15K	-26.2	-35.39	-41.26	-43.10	-16.90
Difference with offset frequency	0.7	1.09	0.24	0.4	

LTE ETM1.1 CF:1GHz, 0dBm					Difference with offset level
PN offset level [dBc/Hz]	-90	-100	-110	-120	
Start Freq[Hz]	EVM [dB]				
100	-26.8	-36.1	-43	-44.50	-17.70
1K	-26.6	-36.1	-42	-43.50	-16.90
5K	-24	-35	-41.5	-43.40	-19.40
10K	-21	-32.6	-40.8	-43.10	-22.10
15K	-19	-31.8	-39.2	-41.60	-22.60
Difference with offset frequency	7.8	4.2	3.8	2.9	

Table 2 shows the comparison of EVM results according to phase noise level at 15 kHz frequency offset which is identical with the interval of sub-carriers of LTE. The noise at the interval of 15 kHz was found to worsen ICI and have a significant impact on EVM performance.

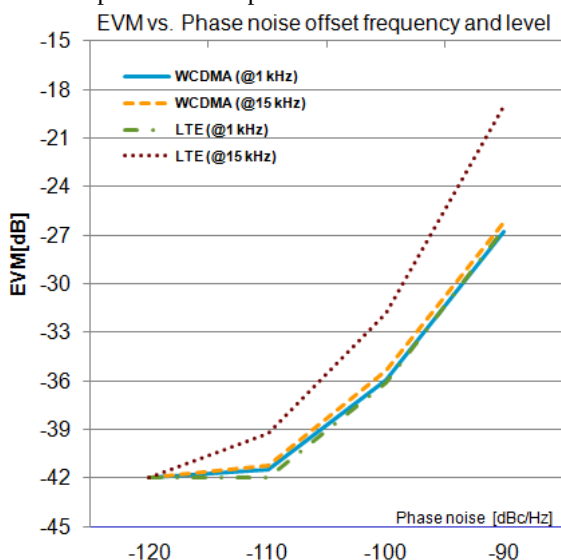


Figure 11. EVM Comparison based on Phase Noise Frequency and Level Offset

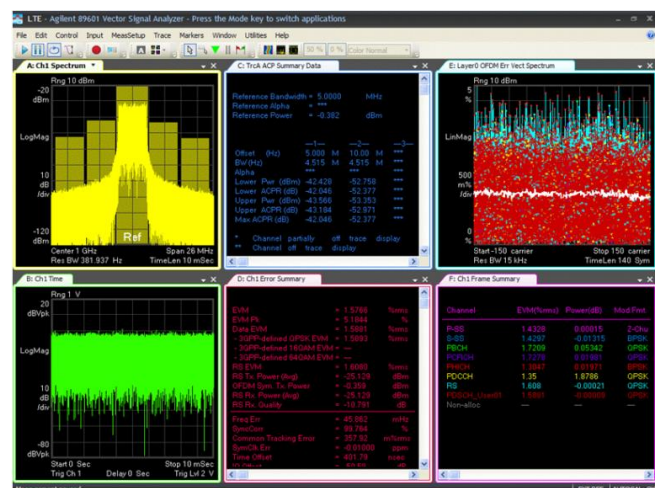


Figure 12. LTE Signal Measured by 89601B VSA Software

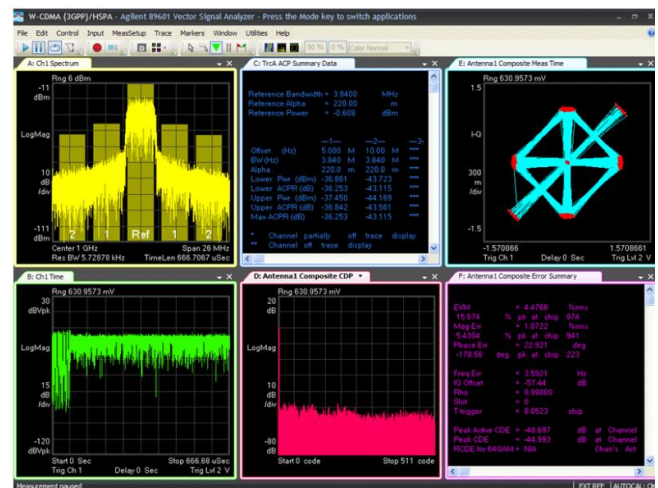


Figure 13. WCDMA Signal Measured by 89601B VSA Software

2) ACP Performance Comparison: There was no change according to phase noise frequency offset and level offset in both the methods. Figure 13 indicates comparison of ACP performance in the level offset of -90dBc/Hz and both the methods showed similar characteristics.

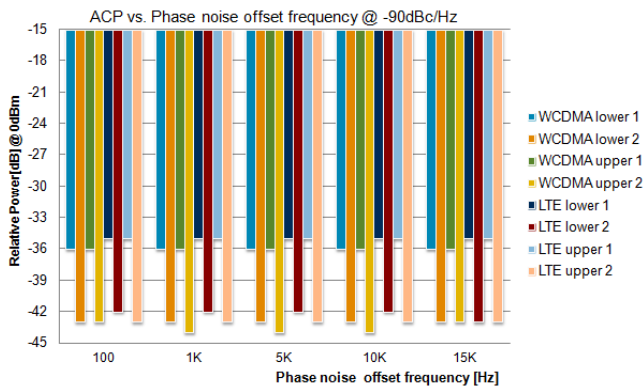


Figure 14. ACP test result according to phase noise frequency offset (-90dBc/Hz)

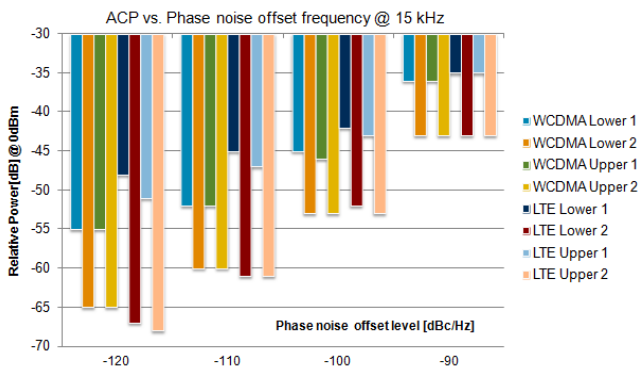


Figure 15. ACP test result according to phase noise level offset (@ 15 kHz)

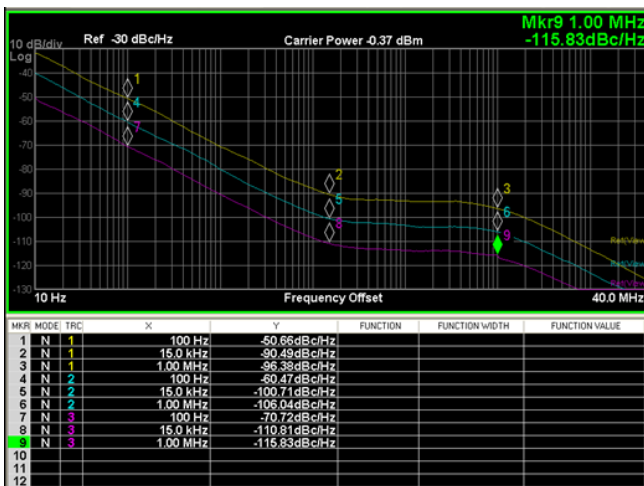


Figure 16. Phase noise characteristic of MXG added with impairment at 15 kHz

IV. CONCLUSIONS

This paper conducted tests to find influences of phase noise on OFDM transmission signal and comparison with SCM for

signal quality. According to the test results, there was maximum 8 dB change in the EVM results according to phase noise offset frequency at a certain offset level in the case of LTE Downlink which arranges orthogonal sub-carriers at an interval of 15 kHz. Especially, the phase noise offset frequency of more than 5 kHz was found to have an impact on the EVM performance.

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