Analysis of Frequency Offsets and Phase Noise Effects on an OFDM 802.11 g Transceiver

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Summary
Since WLAN OFDM Transceiver on both IEEE 802.11a and IEEE 802.11b is the most usable technique to achieve a high performance communication, we can, by means of some modifications evaluate an IEEE 802.11g Transceiver behavior against some link impairments as frequency offset, Inter-carrier interference, phase noise, etc.
In this paper, we focus on the analysis of simulation results of a link impairments applied on a WLAN OFDM Modulation. More specifically, we use the power of ADS [1] 2005A simulation techniques to evaluate phase noise and Frequency Offsets Effects on an OFDM 802.11 g Transceiver.
Key words:
OFDM, WLAN Transceiver, IEEE 802.11g, Frequency Offset, Phase Noise.

Introduction

Needs for wireless communications grow in domains of our daily life and particularly in industrial domain. The near future shows new industrial equipments, connected together, within wireless networks that permit to have an increased versatility in the management of disparate equipments[1], [10]. As a consequence, researchers are developing technologies that will eventually lead to a fully integrated single chip OFDM transceiver based on CMOS technology [7]. On The other hand OFDM symbol is sensitive to many link impairments as frequency offset, Inter-carrier interference, phase noise, average ratio, IFFT/FFT complexity, intersymbol Interference, etc. In this paper we propose an all detailed analysis of frequency offset and phase noise effects on an OFDM IEEE 802.11g Transceiver using an integrated design and simulation environment. The simulation results of the transceiver behavior against those impairments will be presented and access simulation techniques, transceiver architecture and design methodology will be discussed.

2. Concept of OFDM

OFDM is a type of multi-carrier modulation in which single high-rate bit stream is converted to low-rate N parallel bit streams. Each parallel bit stream is modulated on one of N sub-carriers. Each sub-carrier can be modulated differently. For example, BPSK, QPSK or QAM. To achieve high bandwidth efficiency, the spectrum of the sub-carriers is closely spaced and overlapped. Nulls in each sub-carrier's spectrum land at the center of all other sub-carriers (orthogonal). OFDM symbols are generated using IFFT.

3. Advantages of OFDM

OFDM prove robustness in multi-path propagation environment [1]. Due to the use of many sub-carriers, OFDM is more tolerant of delay spread. In fact the symbol duration on the sub-carriers is increased, relative to delay spread so it's clear that the inter-symbol interference is avoided through the use of guard interval. It Simplified or eliminate equalization needs, as compared to single carrier modulation. It is also more resistant to fading. FEC is used to correct for sub-carriers that suffer from deep fade.

4. Design challenges of OFDM modulation

Practically, OFDM symbol is sensitive to frequency offset (need frequency offset correction in the receiver) [4]. It is also sensitive to oscillator phase noise ("clean" and stable oscillator required). That is not the only challenge; OFDM presents a large peak to average ratio (amplifier back-off, reduced power efficiency), an IFFT/FFT complexity (fixed point implementation to optimize latency and performance) and an intersymbol Interference (ISI) due to multi-path-use as shown in figure 1.

[1] Advanced Design System (ADS) is an electronic design automation software system produced by Agilent EEsof EDA [11], a unit of Agilent Technologies. It provides an integrated design and simulation environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, and radar systems.

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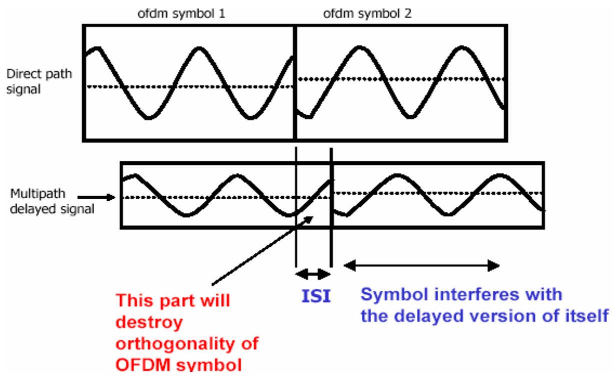

Fig. 1 Intersymbol Interference due to multi-path-use in OFDM Modulation

The multi-path delays up to the guard time do not cause Inter-Symbol Interference, and sub-carriers remain orthogonal for multi-path delays up to guard time (no Inter- Carrier Interference).

To reduce spectrum splatter, the OFDM symbol is multiplied by a raised-cosine window, w(t) before transmission to more quickly reduce the power of out-of-band sub-carriers. Figure 2 shows spectra for 64 sub-carriers with different values of the roll-off factor, ß of the raised cosine window. It does mean that more ß is large better is the spectral roll-off. However, a roll-off factor of ß reduces delay spread tolerance by a factor of ßTS.

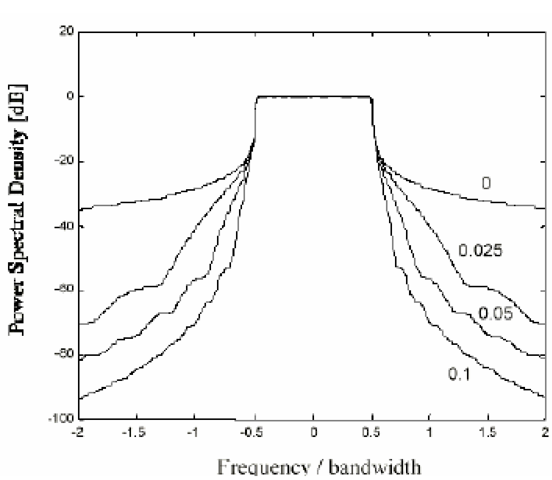

Fig.2 Windowing with different values of roll-off factor used before transmission to reduce the power of out-of-band sub-carrier

5. Sources of link impairments

In OFDM link, the sub-carriers are perfectly orthogonal only if transmitter and receiver use exactly the same frequencies, any frequency offset results in Inter-Carrier Interference (ICI). Figure 3 shows how integer number of cycles of the sub-carrier ensures that the nulls of the spectrum lands on the FFT bin, condition to avoid inter-carrier interference (ICI).

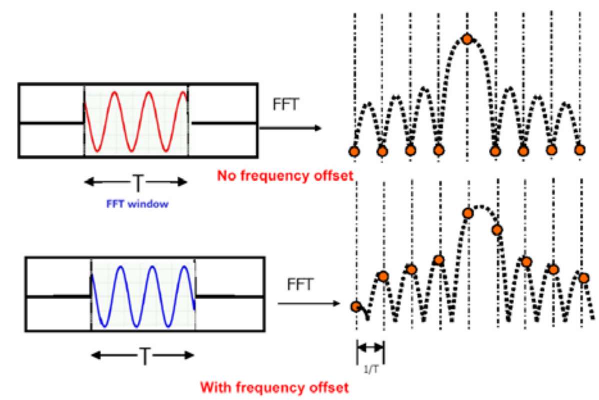

Fig. 3 Inter-Carrier Interference (ICI) due to frequency offset simulated with ADS.

The result of Effects of frequency offset without frequency correction is shown in figure 4 in which frequency offset is expressed as a percentage of sub-carriers frequency spacing (Δf=312.5kHz):

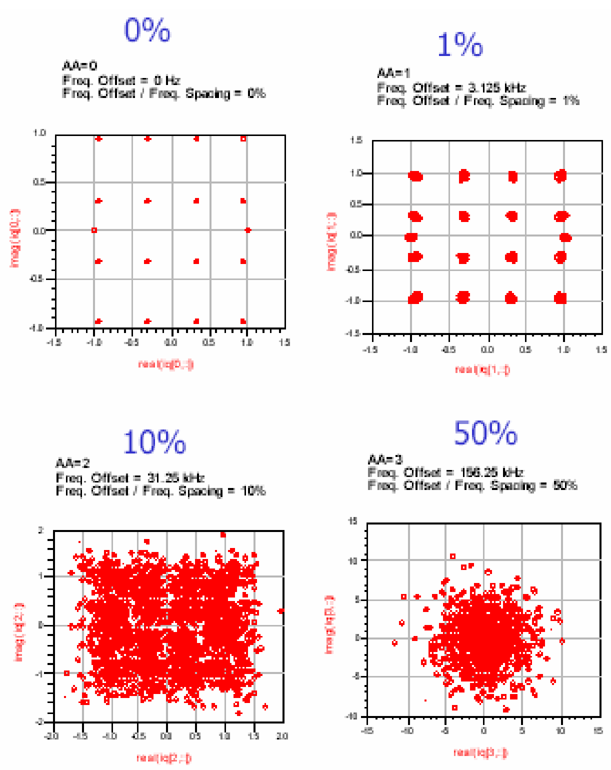

Fig. 4 Result of Frequency Offset without frequency correction simulated with ADS.

To answer to this inconvenient we use a short preamble for coarse frequency offset estimation and a long preamble for fine frequency offset estimation [4]. Where short preamble symbol duration of 0.8µs allows frequency correction up to 1/(2x0.8µs)=±625kHz and the tolerable frequency offset (worst case) = 0.5x625k/5.8G = ±53.8ppm > ±20ppm specified in [4]. The frequency offset compensation network is shown in figure 5.

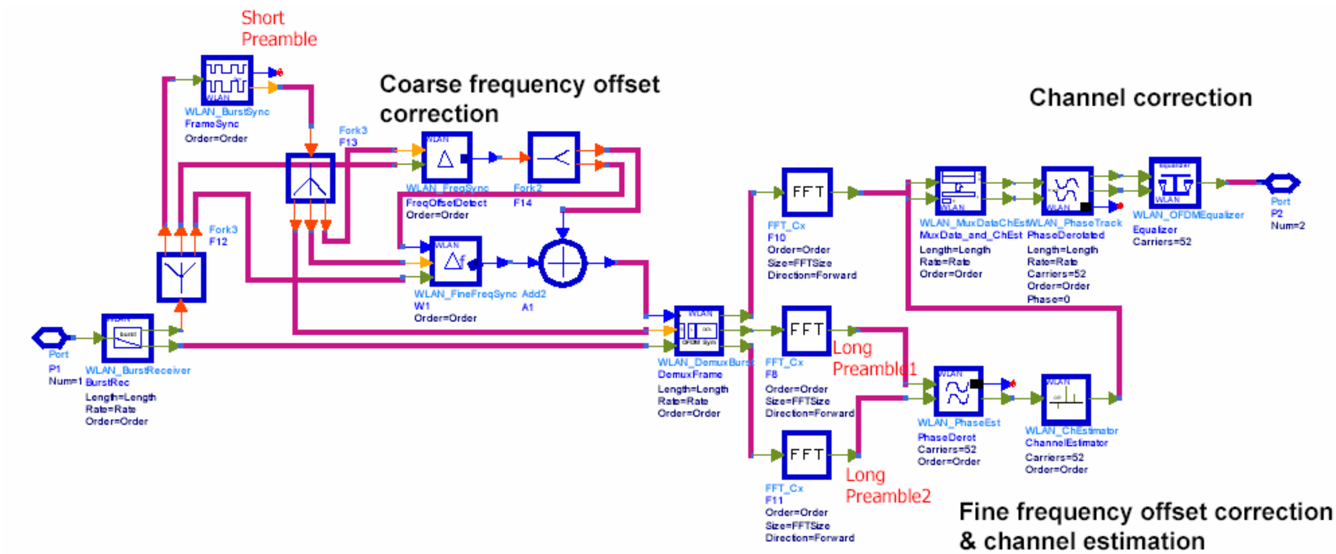

Fig. 5 Frequency offset compensation network designed with ADS

Figure 6 presents the effects of frequency Offset with frequency correction in which frequency offset is expressed as a percentage of sub-carriers frequency spacing (Δf=312.5kHz):

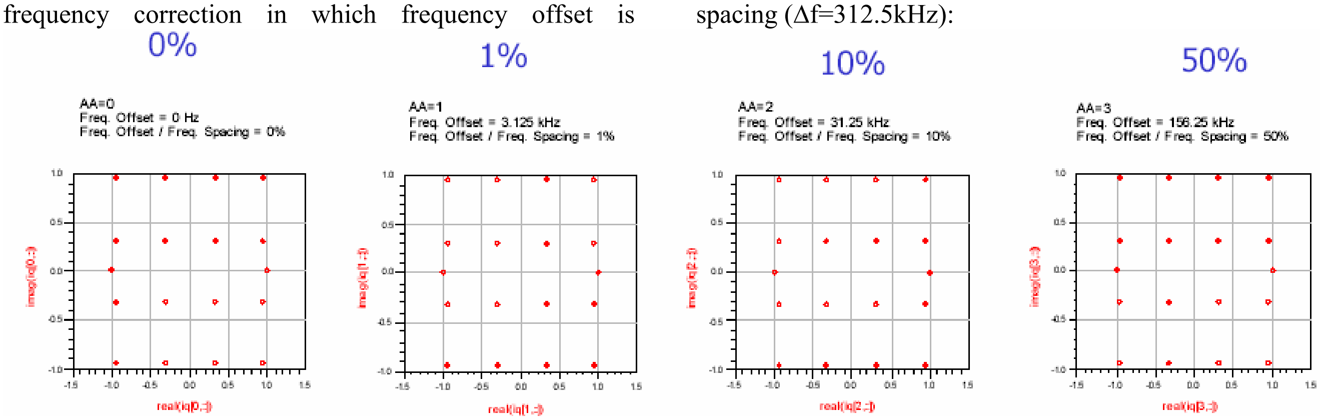

Fig. 6 Result of Frequency Offset with frequency correction simulated with ADS

6. Effects of Oscillator Phase Noise

We know that a practical oscillator does not produce a carrier at exactly one frequency [6], but rather a carrier that is phase modulated by random phase jitter. As a result, the frequency is never perfectly constant, thereby causing ICI.

To model the phase noise we use for this modelisation a ADS (Advanced Design System) N_Tones model [11], based on Lorentzian spectrum and characterized by –3dB-linewidth, -20dB per decade slope given by:

$$S_s(f) = \frac{2/\pi f_l}{1 + f^2/f_l^2} \qquad (1)$$

where f_l = -3dB linewidth

3 profiles of phase noise were simulated each one is determined by a VAR model which gives PN as follow:

PN0=" "

PN1=" 120 -15 300 -23 3000 -43 30000 -63 300000 -83 1200000 -95"

PN2=" 120 -35 300 -43 3000 -63 30000 -83 300000 -103 1200000 -115"
Where PN=if (AA==0) then PN0 elseif (AA==1) then PN1 else PN2 endif.

The effect of oscillator phase noise on the three profiles is shown in figure 7 and the bit error rate of the received signal is shown in figure 8.

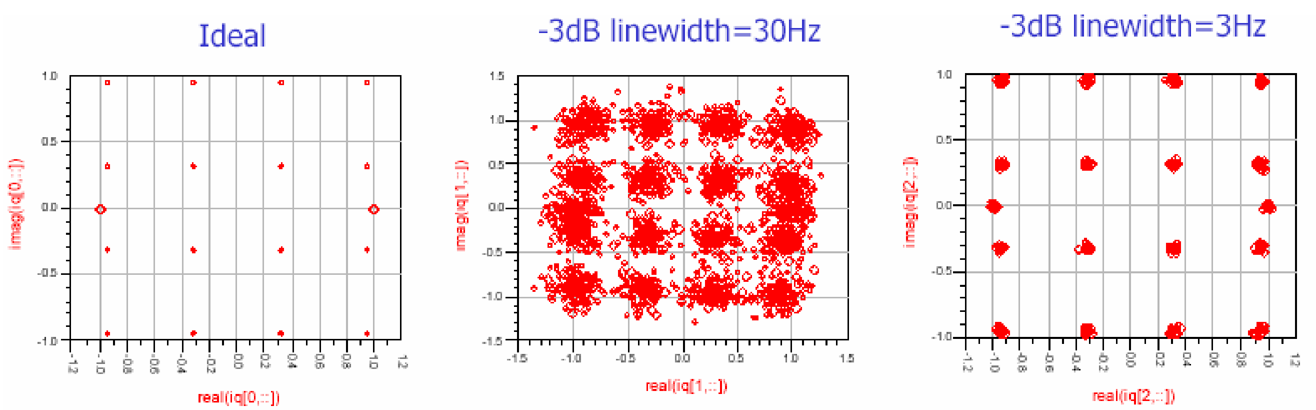

Fig. 7 Result of Effects of Oscillator Phase Noise simulated with ADS

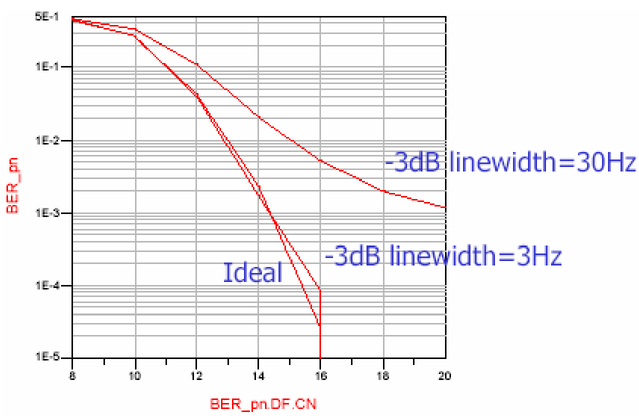

Fig. 8 Bit Error Rate of the received signal of the three profile simulated with ADS

7. Conclusion

We outline in this paper a promising analyzing method of the effects of phase noise and frequency offset on the performance of an OFDM 802.11g transceiver. Access simulation techniques, transceiver architecture, design methodology, detailed measurement results were discussed. The simulation results of the transceiver behavior against those impairments were also presented

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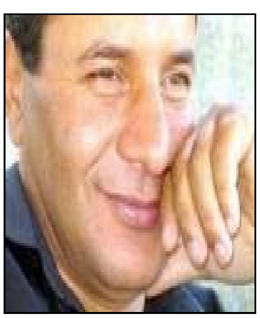
8. Short Biography

Mourad Melliti was born in 1977 in Manouba, Tunisia. He received the degree in electrical engineering from National School of Engineering of Tunis, Tunisia, in 2001, and the postgraduate research degree in digital communications, in 2003, from National School of Engineering of Tunis, since 2003 he is a PHD student in the Department of Computer and Communication Technologies of National School of Engineering of Tunis in Tunis El Manar University of TUNISIA. His research interests are mobile communication systems, wireless Transceivers and wireless access network using ADS platforms.

Dr. Salem Hasnaoui is a professor at the Department of Computer and Communication Technologies at the National School of Engineering of Tunis. He received the Engineer diploma degree in electrical and computer engineering from National School of Engineering of Tunis. He obtained a M.Sc. and third cycle doctorate in electrical engineering, in 1988 and 1993 respectively. The later is extended to a PhD. degree in telecommunications with a specialization in networks and real-time systems, in 2000. He is author and co-author of more than 40 refereed publications, a patent and a book. His current research interests include real-time systems, sensor networks, QoS control & networking, adaptive distributed real-time middleware and protocols that provide performance-assured services in unpredictable environments. He is the responsible of the research group "Networking and Distributed computing" within the Communications Systems Laboratory at the National School of Engineering of Tunis. He served on many conference committees and journals reviewing processes and he is the designated inventor of the Patent "CAN Inter-Orb protocol- CIOP and a Transport Protocol for Data Distribution Service to be used over CAN, TTP , FlexCAN and FlexRay protocols".



Ridha Bouallegue was born in Tunis, Tunisia. He received the M.S degree in Telecommunications in 1990, the Ph.D. degree in telecommunications in 1994, and the "Habilitation a Diriger des Recherches" (HDR) degree in Telecommunications in 2003, all from National School of Engineering of Tunis (ENIT), Tunisia. He is currently Director of National School of Engineering of Sousse. Prof. Ridha Bouallegue is the responsible of the research group within the Communications Systems Laboratory at Sup'Com. His current research interests include mobile and satellite communications, Access technique, intelligent signal processing, CDMA, MIMO, OFDM and UWB systems.