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QPSK-OFDM Carrier Aggregation Using a Single Transmission Chain

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Abstract — To increase the data throughput in Radio Frequency (RF) communication, several coding techniques, different modulations and other secondary parameters can be improved, however the most important factor is the available bandwidth. Carrier Aggregation (CA) is the method proposed in the standardization of LTE-Advanced (LTE-A) by 3rd Generation Partnership Project (3GPP) in order to achieve up to 100 MHz of bandwidth. In this paper a method for generating carrier aggregated Orthogonal Frequency Division Multiplexed (OFDM) signals using a single transmitter chain is presented, moreover the demodulation results obtained by a Tri-Phase Demodulator (TPD) are presented.

Index Terms — LTE-A, carrier aggregation, OFDM, single chain modulation, tri-phase demodulator.

I. INTRODUCTION

OFDM is the communication technique used for LTE-A in order to overcome the wireless communication channel effects. Another important technique that is used for this mobile system is the CA. There are three types of CA: contiguous band CA, non-contiguous intra-band CA and non-contiguous inter-band CA [1]. Several architectures for CA have been proposed in literature, in [2] three transmitter architectures are mentioned. Two of the architectures consist of having a transmitter chain by frequency band. The third one supposed to generate two frequency bands, by one transmission chain, which is suitable for continuous band CA. In another approach, a method, based on zero padding between symbols, is used to generate signals at two frequency bands which requires a long Fast Fourier Transform (FFT) when frequency bands are far from each other [3]. Kaissoine et al. use a CA method, based on using a transmitter chain by frequency band, for more than two frequency bands dedicated for modulation and demodulation of Quadrature Phase Shift Keying (QPSK) modulated signals. In other words, in order to have three frequency aggregated bands, one should use three RF transmitters and three Local Oscillators (LO) for a complete modulation and demodulation process [4]. This equipment design increases the energy consumption and the production cost of the system. However a method to generate several Continuous Wave (CW) signals using a single signal generator is explained in [5]. It allows creating several LOs from one. In that way, the transmitter and receiver chains should become lighter.

This paper presents the frequency diversity that can be used in CA communication using a single transmission chain which consists of one In-phase (I) and In-quadrature (Q) modulator, one Digital to Analog Converter (DAC), one power amplifier and etc. Section II describes the generation

and time domain synchronization procedure of the QPSK-OFDM signal. The proposed CA method is demonstrated in section III. Subsequently, demodulation constraints and its results are presented in section IV. Finally, the conclusion is mentioned in section V.

II. QPSK-OFDM SYMBOL GENERATION AND TIME DOMAIN SYNCHRONIZATION

Frequency selective channels are considered as one of the main problems of RF communications. Hence, OFDM technique was introduced in 60's to overcome this issue by dividing the transmitter required bandwidth into smaller subbands, which makes the channel look flat for our symbol duration (T).

A. QPSK-OFDM Symbol Generation

The structure is quite simple, as shown in Fig. 1, the sequence of QPSK symbols are injected to a serial to parallel converter, then, the N-sized Inversed-FFT (IFFT) is applied to the symbols to divide the signal bandwidth (B) to sub-bands of bandwidth B/N. Next, parallel symbols are converted into serial form. Due to the time delayed multi-path signals that arrive to the receiver, which cause inter symbol interference, a Cyclic Prefix (CP) is added to the sequence of symbols, simply by taking L number of symbols from the end of the sequence and injecting them to its beginning (L must be greater than number of coefficients of the channel corresponding filter), Fig. 2. In the last DSP step, the time domain symbols are filtered using a square root raised cosine filter.

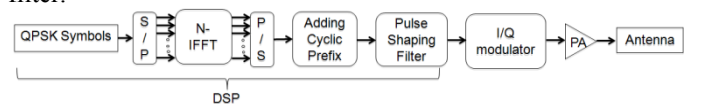


Fig. 1. OFDM signal modulation and transmission chain

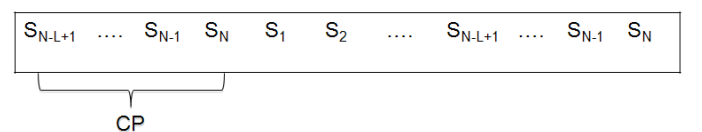


Fig. 2. L last symbols are used as cyclic prefix

B. Time Domaine Synchronization

In communication systems, transmitters and receivers should agree on the data that are being sent and received, hence, a predefined set of symbols, called Training Sequence (TS), are sent before the main data. Many TSs have been proposed in the literature, for instance, Constant Amplitude Zero Autocorrelation (CAZAC) is a common TS [6]. In this

work another widely used TS is implemented in which zeros are transmitted on even frequencies and QPSK symbols are transmitted on the odd ones [7]. Table I shows the configuration of our TS for a case of $N=8$.

TABLE I
Training Sequence Illustration

Frequency Number	Training Sequence
1	-0.707- 0.707j
2	0
3	0.707- 0.707j
4	0
5	0.707+ 0.707j
6	0
7	-0.707+ 0.707j
8	0

At the receiver a Minimum Mean Squared Error (MMSE) algorithm allows to detect the TS, hence the receiver will be synchronized with the transmitter. Moreover, the frequency synchronization is established by connecting the transmitter and receiver to a common 10 MHz clock signal.

III. QPSK-OFDM CARRIER AGGREGATION

This method is applicable on all forms of CA. One can generate several CW signals using the method given in [5]. By modulating these CW signals with the OFDM signal presented in section II, CA is achievable. For a case to generate 3 CW signals at frequencies f_1 , f_2 and f_3 ($f_1 < f_2 < f_3$), one could write I/Q signals as

$$I_3(t) = (1 + 2\cos(2\pi \frac{f_1 - f_2}{2} t)) \cos(2\pi \frac{f_1 + f_2 - 2f_3}{4} t) \quad (1)$$

$$Q_3(t) = (-1 + 2\cos(2\pi \frac{f_1 - f_2}{2} t)) \sin(2\pi \frac{f_1 + f_2 - 2f_3}{4} t) \quad (2)$$

$$f_{c_3} = \frac{f_1 + f_2 + 2f_3}{4} \quad (3)$$

Where f_{c_3} is the needed carrier to up-convert the CW baseband signals ($I_3(t) + jQ_3(t)$) to RF carriers. Here, the period of the baseband signal is the least common multiple of the periods of the components of $I_3(t) + jQ_3(t)$. If this period is not respected, phase discontinuity can happen in the signal generator that leads to periodic spectral re-growth and distortion.

In order to modulate these three carriers with OFDM signal, the baseband signal can be re-written as:

$$I(t) + jQ(t) = (I_{\text{OFDM}}(t) + jQ_{\text{OFDM}}(t)) \cdot (I_3(t) + jQ_3(t)) \quad (4)$$

Where $I_3(t)$, $Q_3(t)$, I_{OFDM} and Q_{OFDM} are in-phase and in-quadrature component of the CW baseband signals and

OFDM signal, respectively. One important remark is that the sampling rate of the OFDM signal and the CW baseband signals are different. Based on the Nyquist criterion, the sampling frequency f_s should be at least twice the signal bandwidth, as shown in equation (5).

$$f_s \geq 2\Delta f \quad (5)$$

Where $\Delta f = f_3 - f_1$.

However, the bandwidth (B) of the OFDM signal is smaller than Δf , hence one should oversample the OFDM signal so that the two signals are sampled at the same sampling frequency.

In Fig. 3 the feasibility of the proposed method is shown. I/Q data of (4) are generated using Matlab[®] and sent to Agilent N5172B signal generator. The three QPSK-OFDM signals with $N = 32$, $L = 8$, bandwidth of 1.35MHz and bit rate of 1.6 Mb/s are generated at 2.8 GHz, 2.82 GHz and 2.86 GHz at -25dBm.

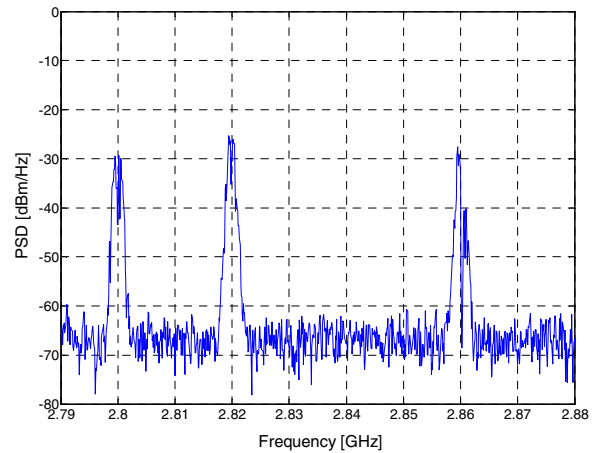


Fig. 3. Three OFDM aggregated bands of 1MHz at 2.8 GHz, 2.82 GHz and 2.86 GHz.

In the next section we will see how to demodulate these three QPSK-OFDM carrier aggregated signals.

IV. SIGNAL DEMODULATION

The demodulation was performed using a TPD [8]. RF signals are down-converted using mixers to Low Intermediate Frequency (LIF) and then each LIF signal band is transposed to baseband and low pass filtered in order to remove the effect of adjacent channels. Next the TS is detected using MMSE algorithm developed for TPD [9]. Once the synchronization is done, the time domain data are converted from serial form to parallel. When CP of each OFDM symbol is removed these symbols pass through a N-size FFT algorithm. Next, the frequency domain data are reshaped to serial form. Symbols

are distorted in TPD; hence a correction algorithm is applied to them [9].

The three signals, presented in Fig. 3, are down-converted to 3MHz, 7MHz and 13MHz with different LOs of -10dBm set to 2.797 GHz, 2.813 GHz and 2.847 GHz. The digital signal processing procedure is applied to the symbols at the I/Q output ports of the I/Q regeneration board of the TPD as explained before. Fig. 4 depicts the test bench of the overall system

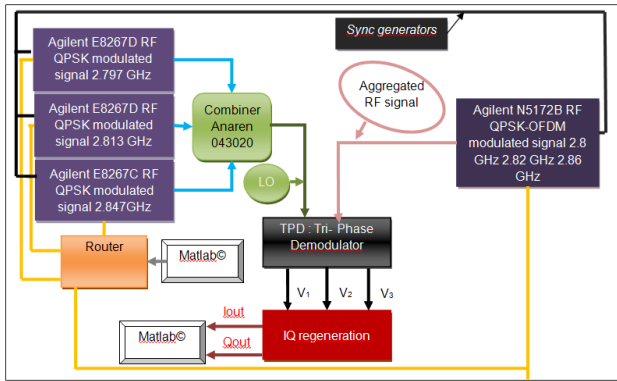


Fig. 4. Measurement test bench

Fig. 5 depicts QPSK constellations of our received symbols. The dispersions in the constellations of Fig. 4 (a) and (b) are due to the non linearity of the mixer (harmonics and spurs) that happen when the Δf is not much greater than the highest LIF band. Here Δf is limited by the sampling frequency of the DAC available on Agilent N5172B which is 150 MS/s According to the Nyquist criterion, the used DAC can generate CA signals with Δf up to 75 MHz

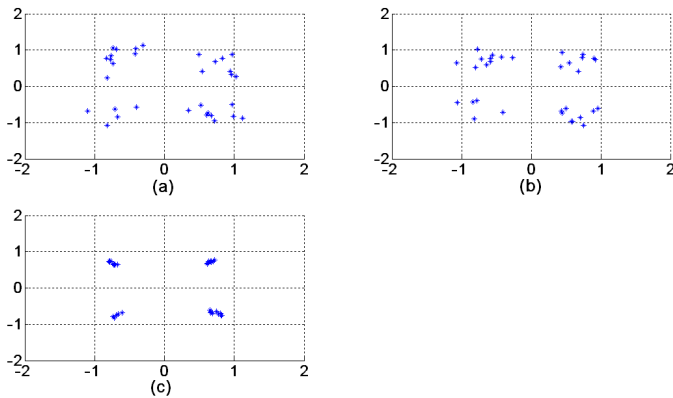


Fig. 5. (a) QPSK, LIF centered at 3 MHz, (b) QPSK, LIF centered at 7 MHz, (c) QPSK, LIF centered at 13 MHz

By turning off two of the LOs, the harmonics and nonlinearities are reduced, however, two undesired LIFs still, happen due to the mixing process of the three RF bands with the LO signal. Fig. 6 (a), (b) and (c) represent the constellation of RF bands at 2.8 GHz, 2.82 GHz and 2.86 GHz down-converted to LIF centered at 13MHz respectively. The comparison with previous results, Fig. 4 (a) and (b),

demonstrates the distortion reduction which is expected since less Intermodulation components and spurs happen close to the LIF band.

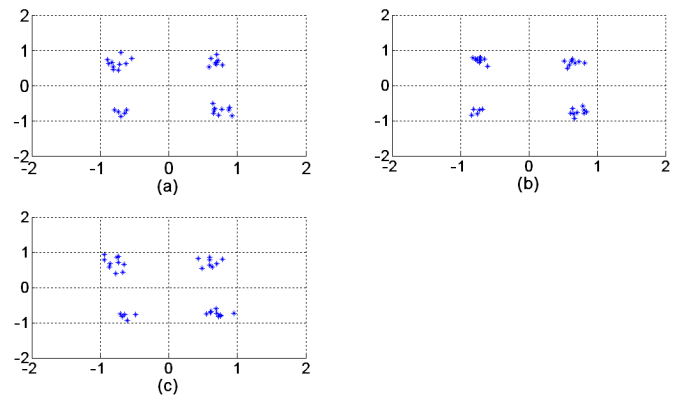


Fig. 6. (a) QPSK,RF @ 2.8 LIF @ 13 MHz, (b) QPSK,RF @ 2.82 LIF @ 13 MHz, (c) QPSK,RF @ 2.86 LIF @ 13 MHz,

V. CONCLUSION

Carrier Aggregation is a method that is proposed in LTE-A. In this paper, we have presented a method to generate with a single transmission chain, three QPSK-OFDM carrier aggregated signals. Moreover, the demodulation process of these signals using a tri-phase demodulator and its limits were discussed. Finally, constellations of the demodulated symbols were presented.

REFERENCES

- [1] L. Doyle, J. McMenamy, and others, "Regulating for carrier aggregation amp; getting spectrum management right for the longer term," in *2012 IEEE International Symposium on Dynamic Spectrum Access Networks*, 2012, pp. 10–20.
- [2] C. S. Park, A. Khayrallah, and others, "Carrier aggregation for LTE-advanced: design challenges of terminals," *Commun. Mag. IEEE*, vol. 51, no. 12, pp. 76–84, 2013.
- [3] F. Nordström, N. Andgart, and others, *Wireless communication methods and receivers for receiving and processing multiple component carrier signals*. Google Patents, 2011.
- [4] A. Kassoine and B. Huyart, "Demodulation of RF Signal Aggregating Four Non-Contiguous Frequency Carriers," in *Electronics, Circuits, and Systems, 2014 IEEE 21th International Conference*, Marseille, 2014.
- [5] M. Abdi Abyaneh, A. Kassoine, and others, "Multiple RF Continuous-Wave Generation Using a Single Signal Generator for Carrier Aggregation in LTE-Advanced," in *European Microwave Conference*, Rome, Italy, 2014.
- [6] J. Meng and G. Kang, "A novel OFDM synchronization algorithm based on CAZAC sequence," in *2010 International Conference on Computer Application and System Modeling*, 2010, vol. 14, pp. V14–634–V14–637.
- [7] T. M. Schmidl and D. C. Cox, "Robust frequency and timing synchronization for OFDM," *IEEE Trans. Commun.*, vol. 45, no. 12, pp. 1613–1621, décembre 1997.
- [8] A. Kassoine, B. Huyart, and K. Mabrouk, "Demodulation of aggregated RF signal in three frequencies bands with a unique Rx chain," in *Microwave Conference, 2013 European*, 2013, pp.561–564.

- [9] G. Neveux, B. Huyart, and G. J. Rodriguez-Guisantes, "Wide-band RF receiver using the 'five-port' technology" *IEEE Trans. Veh. Technol.*, vol. 53, no. 5, pp. 1441–1451, Sep.2004.