CHAPTER 8

CONCLUSION

8.1 SUMMARY

The author can summarise the work presented in this thesis as follows

8.1.1 Introduction to OFDM, PAPR and a PAPR literature review

In Chapter 2 the OFDM concept was introduced. The origin of the high PAPR problem associated with an OFDM transmission was discussed. This high PAPR reduces the battery life of a mobile device, which is not desirable. Various methods have been suggested to reduce the PAPR of an OFDM transmission, these are clipping, decision-aided reconstruction clipping, coding, partial transmission sequence, selective mapping, companding transforms, active constellation extension, tone reservation and CE-OFDM, amongst others. The drawbacks associated with all these methods were discussed.

8.1.2 Introduction of OM-OFDM and a decision metric

In Chapter 3, a novel method called offset modulation was proposed to control the PAPR of an OFDM transmission. The proposed OM-OFDM method was shown not to result in a number of the drawbacks experienced by current methods in the field. The theoretical bandwidth occupancy of the offset modulation signal was derived. Using these bandwidth occupancy results, a closed-form theoretical BER expression for an offset modulation transmission was derived. This mathematically derived BER expression has been shown to agree with the simulated results, thus validating the derivation.

A newly applied decision metric was also introduced, which can be utilised to compare various methods in the PAPR field. This decision metric can also be utilised to investigate whether the proposed OM-OFDM transmission has an optimum solution and whether a net gain exists for such a solution.

8.1.3 Differences between OM-OFDM and CE-OFDM

The proposed OM-OFDM method appears to be similar to a well-known CE-OFDM transmission. In Chapter 4 the significant modulation, structural and performance differences between the OM-OFDM and CE-OFDM methods were demonstrated. In addition, the OM-OFDM method was able to control the PAPR of a transmission accurately for a targeted BER. This is currently not possible with CE-OFDM.

By utilising a power performance decision metric, the OM-OFDM method was shown to offer a net power performance gain of 34 dB and 3.44 dB (at a BER of 10^{-4}) when compared to CE-OFDM and traditional OFDM transmissions for frequency selective fading channel conditions, respectively.

8.1.4 Comparative performance of OM-OFDM

In Chapter 5, the proposed OM-OFDM method was compared to an OFDM transmission as well as existing PAPR reduction methods. A BER comparison between OM-OFDM and OFDM at a PAPR value of 13 dB indicated that both methods offer similar BER characteristics for frequency selective fading channel conditions. Furthermore, when utilising the power performance decision metric, OM-OFDM was shown to offer a net power performance gain of between 4 dB - 1.2 dB (60.4%-23.6%) and 4.1 dB - 1.2 dB (60.8%-23.6%), at a BER of 10^{-4}, for AN10858 and FPD2000AS RF power amplifiers respectively, when compared to clipped OFDM, OFDM, TR and ACE transmissions in a frequency selective fading channel.

Thereafter, by using a CCDF, the OM-OFDM method was shown to offer a PAPR reduction of between 3.2 dB - 2.3 dB (at a CCDF of 10^{-1}) when compared to OFDM, TR, ACE and clipped OFDM transmissions. The proposed offset method was shown to offer a performance improvement when compared to both simple (clipping) as well as more well-established (ACE and TR) PAPR reduction methods, without the need for an iterative (30-60 iterations) process.

8.1.5 Combination of OM-OFDM and ACE

In Chapter 6, the OM-OFDM method was combined with an existing active constellation extended PAPR reduction method. This introduced a novel method called offset modulation with active constellation extension, to control the PAPR of an OFDM signal. A closed-form bandwidth occupancy and theoretical BER expression for this OM-ACE transmission was presented and validated.

Thereafter, by using a power performance decision metric, the OM-ACE transmission was shown to offer a net power performance gain of between 5.7 dB - 2 dB (73.02%-37.71%), at a BER of 10^{-4}, when compared to clipped OFDM, OFDM and ACE transmissions, in a frequency selective fading channel. By using a CCDF, the OM-ACE method is shown to offer a PAPR reduction of between 2.6 dB - 1.6 dB (at a CCDF of 10^{-1}) when compared to OFDM, ACE and clipped OFDM transmissions.

8.1.6 A Cognitive radio application of OM-OFDM

The OM-OFDM method was also proposed for cognitive radio applications. Cognitive radio applications require transmissions that are easily detectable. In Chapter 7 an examination of an OM-OFDM bandwidth occupancy highlights its attractive detection properties. Furthermore, a generic theoretical closed-form relationship between the probability of a missed detection and the probability of a false alarm, for an unknown deterministic signal, was derived and validated. Previous expressions had been derived, which related the P_{md} to P_{fa}. However, they had not been presented in such a generic closed-form expression, which can be used for any unknown deterministic signal (for instance OFDM and OM-OFDM). Thereafter, by using energy detection, the offset modulation method was shown to operate at a 10 dB - 12 dB lower SNR value than an OFDM transmission, while still offering better detection characteristics than an OFDM transmission under Rician, Rayleigh and frequency selective fading conditions. The receiver operating characteristic curves indicate that the P_{md} of an OM-OFDM transmission was between $0.096 - 0.18$ and the P_{md} of an OFDM transmission was between $0.84 - 0.9$ (at a $P_{fa} = 10^{-1}$ and average SNR of -7dB) for Rician, Rayleigh and frequency selective fading channel conditions.

8.2 CONCLUDING REMARKS

In addition to its attractive cognitive radio properties, OM-OFDM also offers good PAPR properties when compared to an OFDM transmission. These performance gains combined with the fact that OM-OFDM requires low implementation complexity and does not lead to a severe BER degradation as the number of carriers increases. Neither does it require any additional bandwidth expansion or the transmission of any side information to reconstruct the original message signal. All these aspects make OM-OFDM a good alternative approach to current methods already in the field.

8.3 FURTHER WORK

8.3.1 Investigate reducing the number of pilot symbols

As discussed in Chapter 3, the OM-OFDM method contains a prominent dominant frequency component. The receiver has knowledge of this dominant component by examining the PAPR of the received transmission. Under flat fading channel conditions, without using pilot symbols, this dominant component can be used to extract CSI, thus eliminating the need for pilot symbols.

This concept can be extended further by dividing an OM-OFDM transmission into smaller multi-user sub-blocks. If under frequency selective fading conditions, flat fading occurs for each sub-block, the number of pilot symbols required would be reduced. This would in turn improve throughput.

8.3.2 Investigate further hybrid OM methods

In Chapter 6, the OM-OFDM method was combined with the ACE method to control the PAPR of an OFDM signal. Various other PAPR reduction methods, such as clipping, DAR clipping, companding transforms and tone reservation, amongst others, can be incorporated in an OM-OFDM transmission to produce other hybrid methods.

8.3.3 Investigate co-operative OM-OFDM sensing for cognitive radio applications

In Chapter 7, a simplified non-cooperative theoretical closed-form relationship, between the probability of a missed detection and the probability of a false alarm for an unknown deterministic signal (e.g. OM-OFDM) was derived. This relationship between P_{md} and P_{fa} can be further extended to investigate co-operative detection characteristics for an unknown deterministic signal.

8.3.4 Synchronisation

In this thesis perfect timing and carrier synchronisation is assumed at the receiver. However, in practice this is not a valid assumption, since these synchronisation aspects severely degrade the BER performance of a system. Thus an interesting research avenue would be to perform an analysis of different synchronisation schemes for an OM-OFDM transmission.

8.3.5 Implementation of an OM-OFDM transmission on a hardware platform

This thesis has presented a mathematical and simulated description of the proposed OM-OFDM method. The next step can be the implementation of the OM-OFDM method onto a hardware platform. For instance, the implementation of OM-OFDM onto a fieldprogrammable gate array (FPGA) board. Such a practical implementation of OM-OFDM would demonstrate the benefits of the method.

8.3.6 Investigate other standards

This thesis focused on the DVB-T2 standard. The various PAPR reduction methods developed can be applied to other standards. For instance if the methods developed in this thesis were applied to LTE, it might remove the current SC-FDMA uplink and replace it with an OFDM uplink instead. This will improve transmitter efficiencies, as well as improve the up-link capabilities of the device.