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Calculation of Peak to Average Power Ratio in OFDM Transmission

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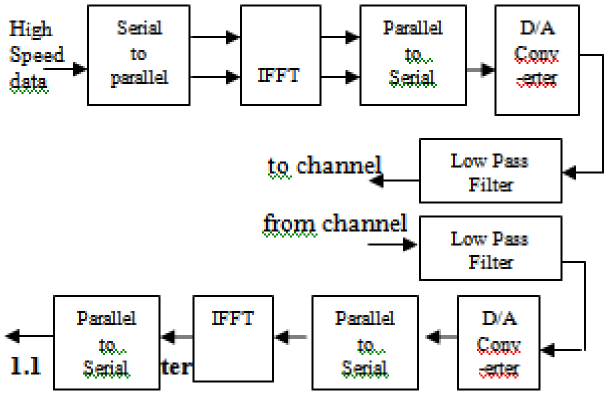
Abstract— **Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has many advantages such as high spectral efficiency, immunity to impulse interference, less non-linear distortion etc. But also the disadvantages such as frequency offset and large Peak-to-Average Power Ratio. Here in this paper the one of disadvantage of OFDM PAPR (Peak to Average Power) is and the proposed method to overcome this limitations are discussed.**

Key Words— **PAPR, OFDM, FFT**

1. INTRODUCTIN TO OFDM

Conceptually, OFDM is a specialized FDM, the additional constraint being: all the carrier signals are orthogonal to each other. In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub-channel is not required. The orthogonality requires that the sub-carrier spacing is Hertz, where TU seconds is the useful symbol duration (the receiver side window size), and k is a positive integer, typically equal to 1. Therefore, with N sub-carriers, the total passband bandwidth will be $B \approx N \cdot \Delta f$ (Hz). The orthogonality also allows high spectral efficiency, with a total symbol rate near the Nyquist rate for the equivalent baseband signal (i.e. near half the Nyquist rate for the double-side band physical passband signal). Almost the whole available frequency band can be utilized. OFDM generally has a nearly 'white' spectrum, giving it benign electromagnetic interference properties with respect to other co-channel users.

The OFDM transmitter and receiver block diagram is shown in the figure below:



1.1 Transmitter

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier is a serial stream of binary digits. By inverse multiplexing, these are first demultiplexed into parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, so some streams may carry a higher bit-rate than others.

An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs); the analogue signals are then used to modulate cosine and sine waves at the carrier frequency, respectively. These signals are then summed to give the transmission signal.

1.2 Receiver

The receiver picks up the signal, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on

, so low-pass filters are used to reject these. The baseband signals are then sampled and digitised using analog-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain.

This returns parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream, , which is an estimate of the original binary stream at the transmitter.

2. IMPLEMENTATION USING FFT

The orthogonality allows for efficient modulator and demodulator implementation using the FFT algorithm on the receiver side, and inverse FFT on the sender side. Although the principles and some of the benefits have been known since the 1960s, OFDM is popular for wideband communications today by way of low-cost digital signal processing components that can efficiently calculate the FFT. The time to compute the inverse-FFT or FFT transform has to take less than the time for each symbol. Which for example for DVB-T (FFT 8k) means the computation has to be done in 896 µs or less. For an 8 192 point FFT this may be approximated to:

$$\begin{aligned}\mathrm{MIPS} &= \frac{\text{computational complexity}}{T_{\text{symbol}}} \times 1.3 \times 10^{-6} \\ &= \frac{147\ 456 \times 2}{896 \times 10^{-6}} \times 1.3 \times 10^{-6} \\ &= 428\end{aligned}$$

Where, MIPS = Million instructions per second

3. MATHEMATICAL DESCRIPTION

If sub-carriers are used, and each sub-carrier is modulated using alternative symbols, the OFDM symbol alphabet consists of combined symbols. The low-pass equivalent OFDM signal is expressed as

$$\nu(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi kt/T}, \quad 0 \le t < T,$$

Where are the data symbols, is the number of sub-carriers, and is the OFDM symbol time. The sub-carrier spacing of makes them orthogonal over each symbol period; this property is expressed as:

$$\frac{1}{T}\int_0^T \left(e^{j2\pi k_1 t/T}\right)^* \left(e^{j2\pi k_2 t/T}\right) dt$$
$$= \frac{1}{T}\int_0^T e^{j2\pi (k_2 - k_1)t/T} dt = \delta_{k_1 k_2}$$

where * denotes the complex conjugate operator.

4. DEFINITION OF PAPR

The crest factor or peak-to-average ratio (PAR) is a measurement of a waveform, calculated from the peak amplitude of the waveform divided by the RMS value of the waveform.

$$C = \frac{|X|peak}{|X|rms}$$

The peak-to-average power ratio (PAPR) is a related measure that is defined as the peak amplitude squared (giving the peak power) divided by the RMS value squared (giving the average power).

$$PAPR = \frac{|x|_{\text{peak}}{}^2}{x_{\text{rms}}{}^2} = C^2$$

Crest factor and PAPR are therefore dimensionless quantities. The PAPR is most used in signal processing applications. As it is a power ratio, it is normally expressed in decibels (dB) as:

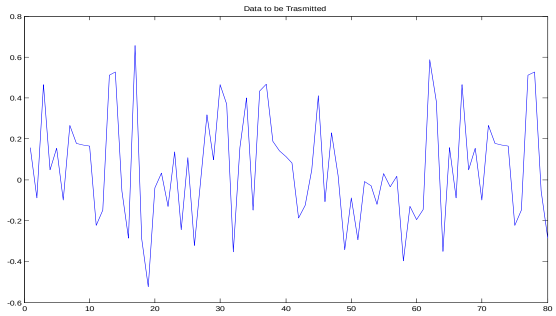
$$\mathrm{PAPR}_{db} = 10 \log_{10} (\mathrm{papr})$$

4.1 Maximum Expected PAPRfrom an OFDM:

OFDM signal is learned as sum of multiple sinusoidal signal having frequency separation 1/T. Where each sinusoidal gets modulated by independent information a_k. Mathematically, the transmit signal is,

$$x(t) = \sum_{0}^{K-1} a_k e^{j2\pi kt/T}$$

The simulated waveform for transmitted data is given below



PAPR is a very well known measure of the envelope fluctuations of a multicarrier signal.

- Used as figure of merit.
- The problem of reducing the envelope fluctuations has turned to reducing PAPR.
- L be $\mathbf{s}^{(m)}$ the m-th OFDM symbol, then its PAPR is defined as:

$$\mathrm{PAPR}_m = \frac{\left\|\mathbf{s}^{(m)}\right\|_\infty^2}{E\left[\left\|\mathbf{s}^{(m)}\right\|^2\right]/N}$$

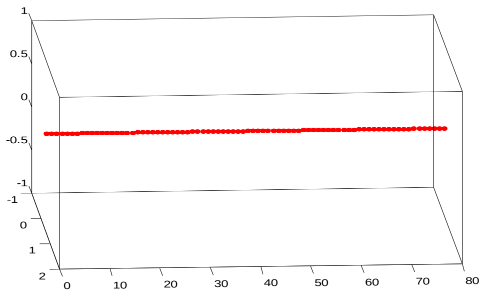
4.1 Consideration on PAPR Reduction

In order to improve the system performance, PAPR should predict the amount of distortion introduced by the nonlinearity. PAPR increases with the number of subcarriers in the OFDM signal. The distortion term and the uniform attenuation and rotation of the constellation only depend on the back-off. The effective energy per bit at the input of the nonlinearity is

$$E_b^{(eff)} = \frac{E_o}{K}\eta_p$$

The approximate PAPR is calculated is 0.0741

The graph is shown in the figure below.



5. Conclusion

The PAPR is one of the important parameter in the OFDM transmission which is calculated fron the above expressions with the help of simulation, the PAPR is calculated as 0.0714. The increased PAPR is main disadvantage of OFDM.

6. Proposed Methods to Reduce PAPR

There are various proposed methods to reduce the Peak-to-Average Power Ratio Such selective mapping, clipping and filetring, PTS algorithm, etc.

7. References

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