# A Survey on Design, Issues and Complexity in OFDM Systems

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***Abstract:*** **Over the last year and half, OFDM communication systems have received significant attention from industry, media and research Organization. The reason for all this excitement is that this technology promises to deliver data rates that can scale from 110 M bit/s at a distance of 10 meters up to 480 M bit/s at a distance of two meters in realistic multi-path environments all while consuming very little power and silicon area. It is expected that OFDM devices will provide low cost solutions that can satisfy the consumer's insatiable appetite for data rates as well as enable new consumer market segments. But for OFDM systems to move from the lab environment to real-life system designs, engineers must battle traditional design issues such as complexity, power consumption, cost, and flexibility. This paper presents and analysis of some key advantages, limitations and available solutions for the system.**

***Keywords:*** **Multi Band Pulsed OFDM, OFDM Systems.**

## I. INTRODUCTION

Federal Communications Commission (FCC) defined OFDM system in terms of the emitted signal bandwidth is more than 20% of its center frequency, or more than 500MHz. In 1998, FCC mandated that OFDM radio transmission can legally operate in the range from 3.1 to 10.6 GHz on an unlicensed basis [1]. The First Report and Order that appeared on 14 February 2002 authorized the operation of OFDM devices under stringent power spectral density emission at 1.3dBm/MHz [2].Since FCC allocated 7500 MHz spectrum forum licensed used, one of the proposed approach is to use multi-band techniques in which the OFDM frequency band is divided into several sub bands. Each sub band occupies a bandwidth of at least 500MHz in compliance with the FCC regulations as shown in Figure 1.The advantage of the multi-band approach allows the information to be processed over a much smaller bandwidth [2], thus reduce the design complexity and lowering the power consumption.

Six band groups are defined in which Band Group 1 to 4 consists of 3 sub-bands, spanning from band 1 to 12.Band Group 5 contains two bands 13 and 14 while Band Group 6 contains bands 9, 10 and 11 as depicted in Figure1.

Relationship between the canter frequency and its band number, n bits given below, in which provides the definition of unique numbering of all channels that are spaced 528 MHz apart where fc and n bits the center frequency and the respective sub band number.

$$f_c(n_b) = 2904 + (528 n_b), n_b = 1,2,\ldots,14 \quad (1)$$

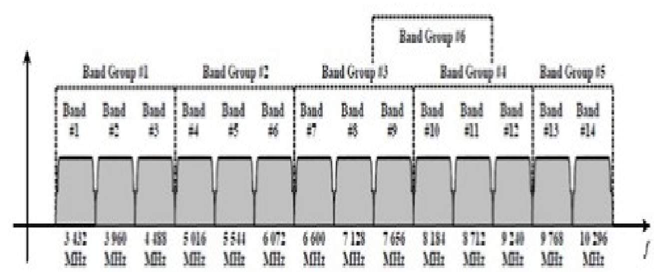


Figure.1 OFDM Frequency Band Planning

However, only three-band is used in the initial deployment of multi-band OFDM systems. OFDM system occupies bandwidths of 528 MHz on each sub band are combined with OFDM techniques [4] in which support of Band Group 1 is mandatory. This system employs 128-point Fast Fourier Transform (FFT) indicates the number of subcarriers on each OFDM symbol. The system parameters on the OFDM scheme used 122-subcarriers carry energy out of 128 FFT point.

  

Of the 122-subcarrier, 100 being used to carry data, 12 are assigned for pilot tones and the remaining ten are guard tones. In OFDM system, each of OFDM symbols are the encoded across all sub-bands by time-frequency code as to exploit frequency diversities and provide robustness against interference. As the matter of fact, multi-band OFDM symbol are not continually sent on one frequency band; instead, they are interleaved over the different sub band across both time and frequency as shown in Figure 2.

By interleaving the symbols across sub-bands, OFDM systems can still maintain the same transmit power as if they were using the entire bandwidth [6]. Multiple access of OFDM system is advantage by the used of frequency-hopping sequences over the set of sub bands.

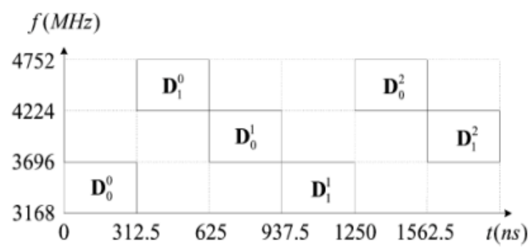


Figure 2. Time-frequency Coding for Multiband OFDM System

## II. ADVANTAGE OF OFDM SYSTEM

### A. MULTI PATH ROBUSTNESS

An OFDM system offers inherent robustness to multi-path dispersion with a low-complexity receiver. Adding a CP forces the linear convolution with the channel impulse response to resemble a circular convolution. A circular convolution in the time domain is equivalent to a multiplication operation in the discrete Fourier transform (DFT) domain. Hence, a one-tap frequency domain equalizer is sufficient to undo the effect of the multi-path channel.

The length of the CP determines the amount of captured multi-path energy. Any multi-path energy outside the CP window would result in inter-carrier-interference (ICI). The CP length should be chosen to minimize the performance degradation due to the loss in collected multi-path energy and the resulting ICI, while still keeping the CP overhead small.

The OFDM channel models are highly dispersive. The worst-case channel environment is expected to have a root-mean-square (RMS) delay spread of 25 ns. Figure 4 illustrates the CP length's impact for the 4 to 10 m, non-line-of-sight (NLOS) channel environment.

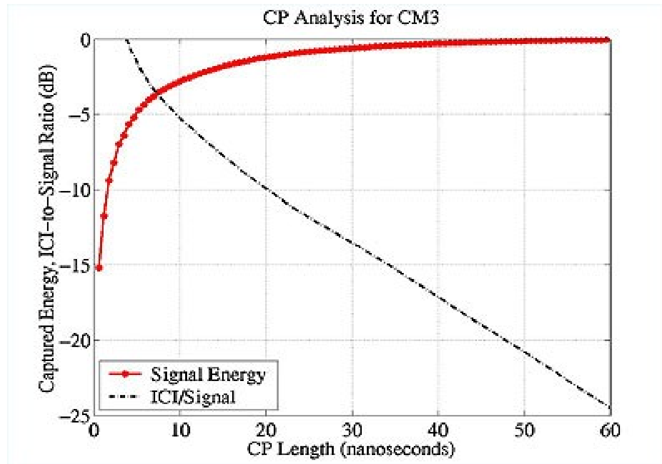


Figure 3: Captured multi-path energy as a function of CP length for a 4 to 10 m, NLOS channel environment.

In Figure 3, the ICI-to-signal ratio is shown at the decoder's input and it incorporates the processing gain for 110 Mbit/s. To sufficiently capture the multi-path energy and minimize the impact of ICI/ISI for all channel environments, the CP duration was chosen to be 60.6 ns.

### B. TONE ALLOCATION

Increasing the number of tones in an OFDM system decreases the overhead due to CP. On the other hand, the complexity of the Fast Fourier transform/inverse Fast Fourier transform (FFT/IFFT) block increases and the spacing between adjacent tones decreases.

To provide the best trade-off between the CP overhead and FFT complexity, the multiband OFDM system uses 128 tones. To be compliant with FCC regulation, the 10-dB bandwidth of an OFDM signal ought to be at least 500 MHz. This implies the use of at least 122 tones.

Hence, the 128 tones are partitioned into 100 data tones, 22 pilot tones and 6 null tones. Among the 22 pilot tones, 12 would be standard-defined pilot tones and 10 would be user-defined pilot tones. The 12 standard-defined pilot tones are sufficient to estimate/track phase variations due to carrier/timing frequency mismatch. To relax the specifications on the channel select filter, the tones at the edge of the spectrum are either null tones or user-defined pilot tones.

  

C. PAPR: A CRITICAL PARAMETER

The peak-to-average power ratio (PAPR) requirement of an OFDM system is a critical parameter in assessing whether the system can be implemented in CMOS. A large PAPR requirement dictates higher peak transmit power for the transmit DAC. Allowing a small percentage of clipping at the DAC can decrease the PAPR.

For an OFDM multi-band OFDM system, restricting the PAPR to 9 dB results in a performance degradation of less than 0.1 dB. In addition, as the FCC has limited the transmit power of OFDM systems to -41.25 dBm/MHz, the average transmit power of a multi-band OFDM system is -9.5 dBm. A PAPR of 9 dB results in a peak transmit power of less than 0 dBm, which is realizable in CMOS technology without the need for an external power amplifier.

D. SPECTRAL FLEXIBILITY

The unlicensed nature of the OFDM spectrum makes it essential for a OFDM device to coexist with other devices that share the same spectrum. In addition, the OFDM spectral allocation could potentially be different in different regions of the world. For example, the Japanese government has encouraged wireless system developers to avoid several narrow bands within the OFDM spectrum that have been allocated for radio astronomy.

Multi-band OFDM can comply with local regulations by dynamically turning off certain tones or channels in the flexibility and dynamic nature of a multi-band OFDM system allows it to coexist effectively with a wide range of current and future wireless technologies. A primary advantage of OFDM is its robustness to narrow-band interferers.

Since the tone spacing is 4.125 MHz, the resolution of the multi-band OFDM system is much narrower than the band resolution of 500 MHz for pulse-based multi-band systems. Any narrow band interference will at most affect a couple of OFDM tones. The information in these tones can be recovered through the forward error correction codes.

E. COMPLEXITY/POWER CONSUMPTION

Some may perceive OFDM as a complex modulation technique, but the multiband OFDM system has been specifically designed to be a low complexity solution. By limiting the transmitted symbols to a quadrature phase-shift keying (QPSK) constellation, the resolution of the DAC/ADC and the internal precision in the digital baseband, especially the FFT, can be lowered. Simulations indicate that 4-bit quantization at the receiver has less than 0.1 dB of degradation for typical data rates.

This system's lower complexity is also due to the relatively large spacing between the carriers when compared to an IEEE 802.11a system. This large spacing relaxes the phase noise requirements on the carrier synthesis circuitry and improves robustness to synchronization errors.

Multiband OFDM has decided advantages over other possible implementations of OFDM in terms of the simplicity as well as the efficiency of its multi-path energy capture. For a clock speed of 102.4 MHz, a 128-point IFFT/FFT, required for multi-band OFDM, performs 10 complex multiplications every clock cycle. This complexity is equivalent to that of a complex 4-tap RAKE receiver, for a single-carrier multi-band implementation, running at 256MHz.

The multiband OFDM system has been specifically designed for a single analog receiver chain. This simplifies the overall architecture considerably; shortening the time to market by allowing the use of currently available and market-tested RF design techniques and components.

F. TIMING JITTER

Timing jitter is emerging as an important factor in determining the performance of high-speed orthogonal frequency division multiplexing (OFDM) systems, particularly in optical OFDM systems where bit rates reach 100 Gbit/s and beyond. It is considered important impairments in very high data rate orthogonal frequency division multiplexing (OFDM) systems because they cause inter carrier interference (ICI) which limits the achievable bit error rate.

## III. OFDMPROPOGATION CHANNEL MODEL

In order to evaluate different PHY layer proposals, IEEE 802.15.3a channel modeling sub-committee proposed a channel model for realistic OFDM environments [7]. During 2002 and 2003, the IEEE 802.15.3 Working Group for Wireless Personal Area Networks, and especially its channel modeling sub-committee decided to use the so called modified Saleh–Valenzuela model (SV) [11] as a reference OFDMchannel model. The real valued model is based on the empirical measurements originally carried out in indoor environments in 1987 (Saleh and Valenzuela, 1987).Due to the clustering phenomena observed at the measured OFDM indoor channel data, the model proposed by IEEE 802.15 is derived from Saleh and Valenzuela using a log-normal distribution rather than an original Rayleigh distribution for the multipath gain magnitude. An independent fading mechanism is assumed for each cluster as for each ray within the cluster. In the SV models, both the cluster and ray arrival times are modelled independently by Poisson processes. The multipath channel impulse response can be expressed as

$$h(t) = \lambda \sum_{l \geq 0} \sum_{k \geq 0} \alpha_{k,l} \delta(t - T_l - \tau_{k,l}) \qquad (3)$$

where $\alpha_{k,l}$ is the real-valued multi-path gain for cluster *l* and ray *k*. The *i*th cluster arrives at time Ti and its *k*th ray arrives at τk,i which is relative to the first path in cluster *l* , ieτ 0,l = 0. The amplitude $\alpha_{k,l}$ has a log-normal distribution and the phase $\angle\alpha_{k,l}$ is chosen from{0,π} with equal probability.

## IV. CONCLUSION

The multi-band OFDM system described in this article provides details about the OFDM communication system with considering advance semiconductor technology featuring low power, low complexity, low cost and the ability to communicate at rates in excess of 110 Mbit/s over distances beyond 10 meters, depending on the data rate and the channel conditions. In addition, systems based on multi-band OFDM have a high degree of flexibility so they can co-exist effectively with existing wireless technologies and adapt to the various regulatory requirements in different regions of the world.

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