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ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is a method of modulation of digital signal in which a signal is divided into many narrowband channels of different frequencies. This technology was first used in the 1960s for the research to minimize interference between channels which are near to each other with respect to frequency. In some points, OFDM and Frequency Division Multiplexing (FDM) are similar to each other. They differ from each other in modulation and demodulation technique of the signal. But in both the cases minimization of the interference, or crosstalk between the channels and symbols forming data stream is given priority and perfection of individual channels is given less importance.OFDM technology is used in European digital audio broadcast services. This technology is also used in digital television and is now being considered as a technique of receiving high-speed digital data over the same conventional telephone lines.

Keywords: OFDM technology, Principles, Characteristics, Advantages, Disadvantages.

I INTRODUCTION

OFDM technology is used for encoding of digital data signal of multiple carrier frequencies. OFDM technology has developed itself as a scheme for wideband digital communication. It is used in digital television as well as audio broadcasting, in DSL Internet access, in wireless networks, and in 4G mobile communications. In this type of technique data on parallel data streams (channels) is carried by a large number of orthogonal sub-carrier signals which are closely spaced. All these sub-carrier are modulated with the help of different conventional modulation scheme like quadrature amplitude-shift modulation (QASK) or phase-shift keying (PSK) at a low symbol rate but in the meantime total data rates must be maintained similar to conventional single-carrier modulation schemes for the same bandwidth.

It is similar to an FDM modulation technique through which a large amount of digital data is transmitted over a radio wave. In OFDM, the radio signal is divided into many small sub-signals which are than simultaneously transmitted to the receiver at different frequencies. The amount of crosstalk is reduced by OFDM in the transmission of signals. OFDM is used in WiMAX, 802.16 and 802.11a WLAN technologies.

In multi-carrier modulation technique a high-bit rate data streams of the data which is to be transmitted is divided into many parallel low bit-rate data streams so as to modulate several carrier signals. Some useful properties of multi-carrier transmission are such as spectrum efficiency and delay-spread tolerance that encourage its use in unethered broadband communications. Due to these properties OFDM has gained popularity in broadband community. This report is intended to provide a tutorial level introduction to OFDM Modulation technique, demerits and its advantages, and some of the applications of OFDM.

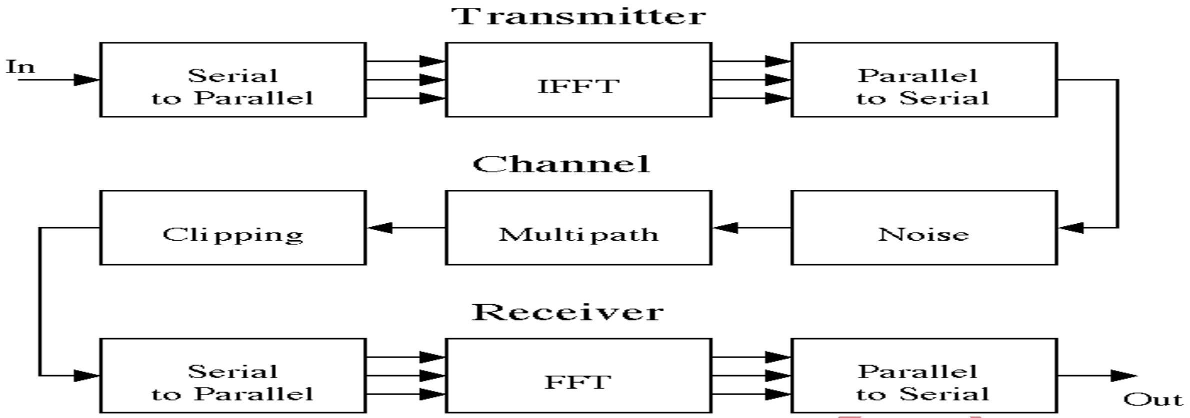

Fig1: OFDM Simulation Flowchart

The input is provided to the serial to parallel register. This serial to parallel register divides the input signal into many parallel outputs. The received parallel outputs used as an input for Inverse Fourier transform device. This device gives the transformed output to the parallel to serial register. This register converts back the parallel data into the serial one. Then the serial signal passes through the communication channel. Noises may be added in the signal while passing through the channel. At the receiver end it s received by again the serial to parallel register the parallel output is then passed through a Fourier transform device which converts it into the original signal. But some amount of noise is also added in the signal. This parallel output signal then passes through parallel to serial register so that a single output can be received.

II PRINCIPLES

Orthogonal Frequency Division Multiplexing (OFDM) follows the basic principle of Orthogonality. OFDM is a type of FDM with the only difference that the carrier signals, used for OFDM modulation, are orthogonal to each other.

In OFDM, the sub-carrier frequencies are selected such that they are orthogonal to each other, so that cross-talk between the sub-channels can be cut short and the requirement of inter-carrier guard bands can be finished. This further simplifies the design of the transmitter as well as the receiver whereas in FDM the use of separate filters for all sub-channels is not required.The orthogonality requires that the sub-carrier spacing is $\Delta f = \frac{k}{T_U}$ Hertz, where T_U 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 has high spectral efficiency, with a total symbol rate near to the Nyquist rate for the equivalent baseband signal (i.e. near half the Nyquist rate for the double-side band physical passband signal). Due to this almost the full available frequency band can be utilized. OFDM generally has a nearly 'white' spectrum which provides it with electromagnetic interference properties with respect to other co-channel users.

A simple example: A useful symbol duration T_U = 1 ms would require a sub-carrier spacing of $\Delta f = \frac{1}{1\,\text{ms}} = 1\,\text{kHz}$(or an integer multiple of that) for orthogonality. N = 1,000 sub-carriers would result in a total passband bandwidth of $N\Delta f$ = 1 MHz. For this symbol time, the bandwidth required in theory according to Nyquist is $N/2T_U$ = 0.5 MHz (i.e., half of the achieved bandwidth required by our scheme). If a guard interval is applied, the required Nyquist bandwidth would be even lower. The FFT would result in N = 1,000 samples per symbol. If no guard interval is applied then this would form in a base band signal of complex value with a sample rate of 1 MHz, for which the required baseband bandwidth would be of 0.5 MHz according to Nyquist Criterion. However, the pass band RF signal can be produced by the multiplication of the baseband signal and a carrier waveform (i.e., double-sideband quadrature amplitude-modulation) and it will result in a pass band bandwidth of 1 MHz. A single-side band (SSB) or vestigial sideband (VSB) modulation scheme would achieve almost half that bandwidth for the same symbol rate (i.e., twice of high spectral efficiency for the same symbol alphabet length). It is therefore quite sensitive to multipath interference.

III CHARACTERISTICS

3.1 Simplified Equalization

The effects of frequency-selective channel conditions can be considered as constant (flat) over an OFDM sub-channel if the sub-channel is sufficiently narrow-banded. . In OFDM, the equalizer multiplies each detected sub-carrier (each Fourier coefficient) in each OFDM symbol by a constant complex number, or a rarely changed value. This makes frequency domain equalization possible at the receiver and is simpler than the time-domain equalization for conventional single-carrier modulation. OFDM is used in wired as well as for stationary wireless communication.

3.2 Channel Coding and Interleaving

OFDM is used in conjunction with channel coding and almost always uses frequency and/or time interleaving. Interleaving is used on OFDM to remove the errors from the bit-stream that is presented to the error correction decoder, as when such decoders are presented with a high concentration of errors the decoder is not able to correct all the bit errors, and a burst of errors which are not corrected, occurs in the sequence. A type of error correction coding used with OFDM systems is convolution coding, often concatenated with Reed-Solomon coding.

3.3 Adaptive Transmission

The dependence on severe channel conditions can be enhanced if information about the channel is sent over a return-channel. According to this received feedback information such type of channel coding and power allocation can be applied across all sub-carriers, or even individually to each sub-carrier. But if a particular range of frequencies faces interference or attenuation, the carriers in that range can be disabled or are run slower by applying more robust modulation or error coding to these effected sub-carriers.

IV ADVANTAGES

4.1Multi-Path Delay Spread Tolerance

The increase in the symbol time of the symbols in OFDM by *N* (*N* is the number of sub-carriers), will lead to the increase in the effectiveness of corresponding OFDM symbol against the ISI which is caused due to multi-path delay spread. On further use, the process of cyclic extension and proper design, ISI can be completely eliminated from the system.

4.2Effectiveness against Channel Distortion

Not only do the delay variations in the channel but also the lack of flatness in the amplitude of the frequency response of the channel cause Inter Symbol Interference (ISI) in digital communication systems. The most common example is the twisted-pair which is used in general telephone lines. Through these transmission lines we can handle voice calls it gives poor frequency response for the transmission of high frequencies. For the single-carrier transmission systems, there may be the requirement of an equalizer so as to mitigate channel distortion effect. The severity of the distortion in the channel will be determined by the complexity of the equalizer and there are also the issues like non-linearities of the equalizer and also error propagation etc that may cause more problems.

On the other hand in OFDM systems, the bandwidth of the sub-carrier is very small and the amplitude response for this narrow bandwidth will be flat and also it can be safely assumed that the phase response is always linear for that narrow bandwidth. Even for extreme distortion in amplitude, an equalizer of simple structure is enough to remove the distortion in sub-carrier.

4.3 Throughput Maximization (Transmission at Capacity)

The usage of sub-carrier modulation will improve the OFDM flexibility of channel fading and distortion also helps in making the possibility for the system of transmitting the maximum capacity possible by using a technique called channel loading. In case, there is a fading notch in transmission channel for certain frequency range for a certain corresponding sub-carrier. If the presence of this notch can be detected using the schemes for channel estimation and also by assuming that the notch will not vary fast enough as compared to the duration of symbol of the OFDM symbol then it is possible to change (scale down/up) the modulation and coding schemes for this particular sub-carrier (i.e., increase their robustness against noise), as a result the capacity as a whole will maximize for all the sub-carriers. However, this will require the data from channel-estimation algorithms. Nothing can be done for such fading notches of single-carrier systems. Therefore, somehow they need to survive this distortion by using equalizers or error correction coding.

4.4 Robustness Against Impulse Noise

Impulse noise is usually a burst of interference caused usually caused in channels such as the return path HFC (Hybrid-Fibre-Coaxial), twisted-pair and wireless channels affected by atmospheric phenomena such as lightning etc. It is common for the symbol duration to be less than the length of the interference waveform of a simple digital communication system. Like, in a 10 MBPS system, the symbol duration is 0.1micro sec, and an impulse noise waveform, which is lasting for a couple of micro-seconds may cause a burst error that cannot be corrected by using simple error-correction coding. This problem can be corrected by using complicated Reed-Solomon codes in conjunction with large interleaves. OFDM systems are inherently robust against impulse noise, since the symbol duration of an OFDM signal is much larger than that of the corresponding single-carrier system and thus, it is less likely that impulse noise might cause (even single) symbol errors. Thus, interleaving schemes and complicated error-control coding for dealing with burst-type errors is not really required for OFDM Systems thereby simplifying the transceiver design.

4.5 Frequency Diversity

Frequency Diversity is best employed in the case of OFDM. In fact, in MC-CDMA transmission technique, which is the combination of OFDM and CDMA, frequency diversity is inherently present (i.e., it is freely available). For this technology, there are a lot advantages provided by OFDM, but it has some serious disadvantages too to be removed so that this technology can be a success. In the following sections we will discuss two serious problems associated with OFDM transmission.

V DISADVANTAGES

5.1 The Peak Power Problem in OFDM

A high peak-to-average ratio is one of the most serious problems exhibited by OFDM transmission. In other words, the problem is of extreme amplitude excursions for the transmitted signal. In general, OFDM signal is a sum of N complex random variables and each of these random variables is considered as a modulated signal which is complex at different frequencies. But in some cases, all the signal components will be added in phase and will produce a large value of output and also in some cases, they can cancel each other by producing a zero output. So the value of peak-to-average ratio (PAR) for the OFDM system will be very large.

5.2 Clipping

An important feature in the OFDM, of the peak-to-average ratio is that the symbols percentage has a very large peak-power (but the increase in number of sub-carriers will decrease the percentage). So in this case, the peak-power problem can be simply solved by clipping, i.e., by limiting the peak signal amplitude to a certain level. Although this method is simple but still it has few disadvantages. Self-interference may be produced due to clipping that can cause decrement in the BER performance. The distortion caused due to clipping is non-linear which can increase the total amount of out-of-band radiation.

The clipping operation is a multiplication of the OFDM symbol with a rectangular function (which means that it is 1 if the amplitude of the signal is below the given threshold and is a smaller value if the amplitude of the signal is above the given threshold) which may increase the out-of-band radiation. The out-of-band radiation increases due to this rectangular function, and the result is that the spectrum has a roll-off which is inversely proportional of the frequency.

5.3 Error-Control Coding

The degradation in BER is one among the many problems of OFDM. Mainly, the symbols with large PAR ratio are more vulnerable to errors. But this effect can be controlled by applying forward error correction (FEC) for several OFDM symbols. If FEC is applied across several OFDM symbols, the errors which are due to large PAR in some particular symbols can be easily corrected by the nearby surrounding symbols.

5.4 Peak Cancellation

The peaks in an OFDM signal can also be removed using other method like by subtracting a scaled reference and time-shifted function in such a way that each subtracted reference function will be reduced by the peak power of minimum one signal sample. It is recommended that the chosen signal should be approximately of the same bandwidth as the transmitted signal is. The sinc function is the most commonly used peak-cancelling function because it has required frequency-domain properties.

5.5 Symbol Scrambling Techniques

The main idea of symbol scrambling technique is that, the input sequence is scrambled by a certain number of scrambling sequences for each OFDM symbol. The transmitted signal is an output signal of smallest PAR value. The probability with scrambling will be pk(given that k is a set of scrambling codes), if the probability of PAR for an OFDM symbol is p. Thus, the probability of high PARs will be reduced due to scrambling, instead of reducing the levels of these PARs.

VI CONCLUSION

OFDM is a method of encoding digital data on multiple carrier frequencies. It is used in many wireless systems. Its main advantage is its ability to cope with severe channel but it has a disadvantage that it has a noise like amplitude with a very large dynamic range. Therefore there is the requirement of RF power amplifiers which have high peak to average power ratio.

References

[1] 2GHz BAS Relocation Tech-Fair, COFDM Technology Basics. 2007-03-02

[2] Robertson, P.; Kaiser, S. "*The effects of Doppler spreads in OFDM (A) mobile radio systems"*, Vehicular Technology Conference, 1999. VTC 1999 - Fall. IEEE VTS.

[3] Haas, R.; Belfiore, J.C. (1997). "*A Time-Frequency Well-localized Pulse for Multiple Carrier Transmission"*. Wireless Personal Communications **5** (1): Roque, D.; Siclet, C. (2013). "Performances of Weighted Cyclic Prefix OFDM with Low-Complexity Equalization". IEEE Communications Letters.

[4] Jeon, W.G.; Chang, K.H.; Cho, Y.S. (1999). "*An equalization technique for orthogonal frequency-division multiplexing systems in time-variant multipath channels*". IEEE Transactions on Communications.