OFDM splits a single data stream into multiple, closely spaced narrowband sub-carriers and transmits these sub-carriers in parallel, enhancing bandwidth efficiency. It utilizes orthogonal waveform combination to prevent sub-carrier interference (Editorial Team, 2023).

**Advantages of using OFDM:**

**Improved Spectral Efficiency**: By transmitting data on multiple sub-carriers.

**Robustness**: The use of narrowband sub-carriers makes the system less susceptible to the phase shift and time delay issues.

**Reduced ISI** (Inter-Symbol Interference): The duration increases due to the narrow bandwidth of each sub-carrier.

**Flexibility in Frequency Selection**: Each sub-carrier can be individually adapted to the channel conditions.

**Orthogonality**: Ensures that the peak of one sub-carrier coincides with nulls of others, minimizing interference.

**Applications**:

**Wireless Communications:**

* **Wi-Fi Networks (IEEE 802.11a/g/n/ac/ax):** OFDM is fundamental to Wi-Fi standards, enabling high-speed internet access in homes, offices, and public hotspots.
* **4G/LTE and 5G Mobile Networks:** OFDM is used in LTE and 5G NR (New Radio) for efficient spectrum use, supporting high data rate mobile internet and communication services.

Digital Broadcasting:

**Digital Television (DVB-T/DVB-T2):** OFDM allows digital TV services to deliver multiple channels and high-definition content over terrestrial frequencies.

**Fixed Wireless Access:**

* **WiMAX (Worldwide Interoperability for Microwave Access, IEEE 802.16):** Offers broadband wireless access over long distances, using OFDM to serve as a wireless alternative to cable and DSL.

**Secure Communications:** OFDM supports robust and secure communication links that are resistant to jamming and eavesdropping, crucial for military operations.

**Radar Systems:** Some modern radar systems utilize OFDM to improve resolution and detection capabilities through multipath exploitation.

**Internet Services**: Satellite ISPs use OFDM to deliver broadband internet services to remote and rural areas where terrestrial internet infrastructure is not available.

**Underwater Acoustic Communications:** It’s used to deal with the challenging propagation environment, including long delays, multipath, and Doppler spread.

**Vehicle-to-Everything (V2X) Communications:**

* **Intelligent Transportation Systems (ITS):** OFDM facilitates communication between vehicles and infrastructure, supporting safety applications and efficient traffic management.

Reference:

Editorial Team. (2023). What is ofdm?. Everything RF. <https://www.everythingrf.com/community/what-is-ofdm>

1. The challenges OFDM faces in modulation or coding scheme are as following(Halford, 2002):

* **Frequency Offset:**

Frequency offset occurs when the receiver's voltage-controlled oscillator (VCO) is not sync with the transmitter's VCO, leading to frequency translation in the signal and an increased error rate. OFDM is particularly sensitive to frequency offsets because it can cause the orthogonal subcarriers to interfere with each other, leading to inter-carrier interference (ICI) and rapid degradation of the error rate.

* **Phase Noise:**

The phase noise is a challenge as it can affect the orthogonality of the subcarriers, leading to ICI and symbol errors.

* **Peak-to-Average Ratio (PAR):**

PAR is a known issue in OFDM systems. High PAR can lead to inefficiencies in the power amplifier, requiring linear amplification to avoid clipping and non-linear distortion, which can lead to power-consuming and expensive.

* **Handling Offset:**

Addressing frequency offset is a significant challenge. Methods used for estimating and removing frequency offset include using training sequences in packet-based systems to aid in estimating the offset and adjusting the VCO frequency accordingly. Reliable estimation of frequency offset is crucial for effective OFDM system design.

* **Guard Interval:**

OFDM symbols are protected from inter-symbol interference (ISI) by adding a redundant symbol extension known as a guard interval. This interval absorbs all the ISI from preceding symbols, which can then be discarded at the receiver to eliminate ISI.

These are the some of the challenges which highlight the complexity of implementing OFDM in wireless system designs, despite its advantages in handling multipath distortion and enhancing data transmission efficiency.

Reference:

Halford, S., & Halford, K. (2002). Ofdm uncovered part 2: design challenges. EDN. <https://www.edn.com/ofdm-uncovered-part-2-design-challenges/>

1. Orthogonal Frequency-Division Multiplexing (OFDM) is particularly suitable for environments where high data rate wireless communication is needed, despite the presence of challenging conditions such as multipath propagation and frequency selective fading (Burke, 2021). Based on the information from the provided link, OFDM is well-suited for the following environments:

* **Wireless Data Transmission**: OFDM is predominantly used in wireless communication due to its ability to efficiently handle multipath reflections and minimize interference, making it ideal for mobile internet, broadband wireless access, and other forms of wireless data communication.
* **Wired and Fiber Optic Communication**: Although less common, OFDM can also be employed in wired and fiber optic communication systems, where its ability to split a single information stream into several closely spaced narrowband sub channel frequencies can be utilized to enhance data transmission efficiency.
* **Digital Broadcasting**: It is used in digital audio broadcasting (DAB), digital radio, and digital television broadcasting standards like DVB-T/H and DVB-C2, where it enables the transmission of multiple channels and high-definition content over terrestrial frequencies.
* **Cellular Networks**: In cellular data networks, including 4G/LTE and 5G New Radio (NR), OFDM supports high data rates and a large number of devices, particularly beneficial for Internet of Things (IoT) applications.
* **Wi-Fi Networks**: All Wi-Fi systems, including IEEE 802.11a/b/g/n/ac/ax, utilize OFDM. The addition of Orthogonal Frequency-Division Multiple Access (OFDMA) to the Wi-Fi 6 (802.11ax) standard allows for more efficient use of the spectrum and supports a higher number of devices simultaneously.
* **High-Speed Internet Services**: OFDM is used in Asymmetric Digital Subscriber Line (ADSL) and cable internet services, as well as IEEE 1901 power line networking, where it helps to maximize the efficiency of data transmission over existing wiring infrastructure.

The key features of OFDM, such as its resilience to electromagnetic interference, efficient use of bandwidth, and advanced error correction capabilities, make it suitable for these environments.

Reference:

Wright, G. & Burke, J. (2021). Orthogonal frequency-division multiplexing (ofdm). TechTarget. <https://www.techtarget.com/searchnetworking/definition/orthogonal-frequency-division-multiplexing>

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