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Improving performance in a Wi-Fi enabled Smart Leather Jacket with integrated sensors through the application of Dual-mode Index Modulation

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Abstract

In light of the recent advancement and use of automated wearable technology, the Smart Leather Jacket has gained popularity, utilizing innovative leather fabrics embedded with sensors to offer enhanced intelligent multi-functions alongside protection from thermal atmospheric conditions. Smart Leather Jacket incorporating sensors, designed for healthcare monitoring or physical activity tracking, typically uses standard wireless communication protocol, Wi-Fi, for remote mobile app-based control and mobile network connectivity to the cloud data server. Such a functional requirement involves the provision of faster and larger data transfer facility through existing mobile signal transmission. In the era of 5G communication technology, Wi-Fi networks predominantly utilize Orthogonal Frequency Division Multiplexing (OFDM) as a key modulation technique to attain elevated data speeds, multipath resilience and robustness against interference. Nevertheless, a new and improved version of the fundamental OFDM signal called Dual-Mode Index Modulation Aided OFDM (DM-OFDM-IM) surpasses the conventional basic OFDM system regarding data throughput, energy efficiency, and reliability in detection. It cleverly combines active subcarrier index-based data with modulation symbol-based data over two non-

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overlapping constellation sets, thereby enhancing the system throughput. This paper proposes the use of the DM-OFDM-IM technique as an alternative high data rate scheme to conventional OFDM for transmitting signals in a Wi-Fi-enabled Smart Leather Jacket equipped with integrated sensors.

Index Terms— Smart Leather Jacket, OFDM, DualMode Index Modulation Aided OFDM, Wi-Fi, data rate.

1. Introduction

As wearable technology evolves from fitness trackers to smart clothing, the Smart Leather Jacket (SLJ) featuring built-in sensors presents a powerful solution that combines modern technological features with the timeless comfort and style of leather [1], [2]. Tech-infused leather jackets incorporate sensor-driven smart technology into traditional leather attire [3]. The objective is to enhance the jacket’s functionality while maintaining its aesthetic appeal, comfort and durability [4]. In addition to providing optimal protection against cold atmospheric adversities, the SLJ incorporates various smart features, including health monitoring through biometric sensors, real-time environmental observation, weather-adaptive thermal regulators, a solar-powered device charger, a Global Positioning System (GPS) tracker, and a range of other valuable applications [5]-[17].

Mobile app-based connectivity of the biometric or environmental sensors housed in a SLJ can be established by using Bluetooth for short range and Wi-Fi for medium range. However, for a moving wearer, standard wireless communication protocol Wi-Fi 6 or 7 is the most proficient choice to handle massive sensor data with low latency and provide secured cellular network connectivity [18]. Wi-Fi 6 (802.11ax) uses Orthogonal Frequency Division

Multiplexing (OFDM) as the core signal transmission technique. OFDM splits data into many narrow subcarriers, making it highly resistant to “multipath fading” and interference [18]. Leather jackets are often worn in urban areas with high signal reflection. Employment of OFDM offers the benefit of low-loss data transmission in the context of an overcrowded signal in an urban environment. By overlapping subcarriers without mutual interference, OFDM maximizes the jacket’s battery life by completing data transmissions faster.

An attractive variant of traditional classic OFDM was evolved in [19], where OFDM with subcarrier index modulation, named OFDM-IM, was proposed to offer improved data transmission reliability by leaving some subcarriers “idle” to convey information through their positions. However, this reduces the overall data rate. Another descendant scheme, called Dual-Mode Index Modulation Aided OFDM (DM-OFDM-IM), developed in [20], solves this problem by activating all the subcarriers, whereas maintaining the benefits of OFDM-IM.

This article explores the prospect of performance improvement in data transmission for a sensor-integrated Wi-Fi-enabled SLJ. In modern wireless standards like WiFi 7, the current protocol employs traditional OFDM for establishing 5G cellular connectivity for mobile app-based control and access to cloud data network [21]. However, in order to transmit and process huge data collected from biological and environmental sensors in a SLJ, exploitation of DM-OFDM-IM can be a promising solution.

2. Methodology

2.1 Specific applications of Smart Leather Jacket:

For professional bikers, walkers, mountaineers or mining workers, a SLJ can be equipped with low-powered LED lights that flash or glow in the dark for making the surroundings more visible in low-light conditions [2]. These lights can have automatically adjustable intensity depending on ambient light and visibility conditions, thereby providing an additional security measure. A SLJ can be equipped with built-in sensors that monitor health-care parameters such as body temperature, blood pressure, heart rate, blood oxygen level, ECG monitoring, pulse rate etc. [9], [11]. There can also be monitoring systems for environmental parameters like surrounding temperature, air pressure, humidity, atmospheric pollution level and other climate conditions. This kind of data can alert the wearer against any drastic variation in health condition due to sudden environmental changes, offer real-time feedback, and help one to take immediate preventive measures, thereby making it a popular choice among fitness enthusiasts, athletes, outdoor professionals and adventurers. One of the most popular uses of SLJ is automatic temperature regulation [10]. Built-in heating elements allow wearers to adjust their warmth according to the environment. These jackets typically have adjustable heat settings that can target key areas like the chest, back, and arms. The schematic diagram of a SLJ with various applications is illustrated in Figure 1.

 Biometric Sensors: Real-time monitoring

of heart rate (MAX30100), ECG (AD8232), and oxygen saturation (SpO2), [1]-[2].

 Environmental Sensors: Detection of harmful

gases (MQ7/MQ135), temperature, and humidity for industrial worker safety [3].

 Location Tracking: Integrated NEO6M

GPS modules for emergency response and navigation [4].

 Control Unit: A centralized ESP32 or similar

microcontroller manages the data flow, using WiFi to push information to cloud platforms like Blynk or Firebase [2].

 Real-Time Mobile Integration: Dedicated

apps provide users with “scenes” (e.g., automatically activating thermal heating when the temperature drops) and remote energy management to optimize battery life [12].

 Advanced Safety: Modern commercial

iterations, such as those from Dainese, already integrate D-air airbag systems that monitor surroundings 1,000 times per second using advanced sensors [13].

Figure 1. Schematic diagram of a Smart Leather Jacket

2.2 Employment of DM-OFDM-IM in SLJ:

Existing Wi-Fi protocol uses traditional OFDM for connectivity over 4G LTE or even 5G mobile communication. OFDM transmits data over a group of orthogonally split subcarriers, each carrying a symbol modulated from input digital data. DM-OFDM-IM uses two different constellation modes of either M-ary QAM or M-ary PSK symbol

sets [19]. Here, information is sent via a) the actual symbols b) through the indices of subcarriers and c) constellation modes of the symbols. Thus DM-OFDM-IM is capable of sending more amount of data over the same number of subcarriers in comparison

to OFDM. It maintains a high data rate while still gaining the diversity benefits of index modulation. DM-OFDMIM significantly outperforms standard Wi-Fi modulation in challenging environments by offering SNR gain of several dBs over standard OFDM-IM in frequencyselective Rayleigh fading channels [22]. By using distinguishable constellation sets, the system increases the “minimum Euclidean distance” between signals, making it harder for noise to cause bit errors. The Wi-Fi connectivity module of a SLJ using DM-OFDM-IM is displayed in Figure 2.

Figure 2. Employment of DM-OFDM-IM in a Smart

3. Results and Discussions

Data transmission parameters for conventional OFDM, index modulated OFDM and DM-OFDM-IM schemes are presented in Figure 3. It is quite evident that information conveyance through the maximum number of parameters makes DM-OFDM-IM the winning scheme to offer the highest data rate. The performance comparison of DMOFDM-IM and other existing OFDM schemes is shown in Table-1, which evidently indicates the optimum performance of DM-OFDM-IM compared to the other existing schemes

Figure 3. Data transmission parameters in different variants of OFDM scheme.

All Active (Two modes) Spectral Efficiency

Optimal (Max distance) Energy Efficiency Standard High (selective activation)

Table-1: Performance comparison

Feature Conventional OFDM (Wi-Fi 5/6)

Subcarrier State All Active Some Inactive (Zero symbols)

High Lower (due to idle carriers)

Detection Error Performance

Standard Better (Diversity)

4. Conclusions

A sensor-driven SLJ with high-speed Wi-Fi connectivity can be a game-changer for hikers, sports and defense professionals, travelers or any outdoor event commuter in a cold climate. Moreover, it can have the ability to charge devices on the go, and staying warm without bulky layers can make travel more comfortable. The jacket’s versatility extends from chronic illness management to elderly care, promising to enhance overall well-being and quality of life. By seamlessly integrating technology into daily life, the AI smart jacket stands as a pioneering solution at the forefront of healthcare innovation. Practical hardware implementation of sensor-integrated SLJ associated with DM-OFDM-IM connectivity offers an interesting research opportunity for upcoming IoT-based 5G and beyond mobile applications. By employing this technology, in near future, it is possible to design Smart Leather Jacket networks, which will allow communication within multiple smart jacket wearers travelling nearby simultaneously, thereby acting promptly upon urgency arising for life-critical SOS alerts. As sustainability becomes a growing concern for consumers, more and more people are opting for smart fashion, which is both functional and eco-friendly. Many of the tech-infused leather jackets incorporate sustainable materials such as laboratory-fabricated cruelty-free leather. They also avail some energy-saving technologies, like solar-powered charging.

Single-Mode

Dual-Mode OFDM-

OFDM-IM

IM

Highest

High

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