Summary on RoF Technologies, Modulations, and Optical Filters: Review

Manea N. Obeid¹, Mishari A. Askar²

¹²Computer Science Department, Collage of Computer Science, Tikrit University, Tikrit, Iraq.

ABSTRACT

In order to meet the growing need for bandwidth, this article offers a thorough examination of Radio over Fibre (RoF) technology and its integration with wireless communication networks. It starts out by going over the development of wireless networks and the difficulties they encounter, like spectral congestion and RF spectrum operational constraints. An effective way to handle data traffic is to include optical fibre into wireless networks. A detailed analysis is conducted of the technical features of RoF systems, including modulation approaches such as external and direct modulation. While external modulation provides better performance by getting around constraints, direct modulation uses the RF signal to directly modify the brightness of the light source. It is detailed how optical filters, including Fabry–Perot, Fiber–Bragg Grating, and Tunable filters, are used in a variety of applications. They provide an explanation of their functions and importance in optical communication. In addition, a thorough review of relevant literature is included in the study, along with a summary of the main conclusions, approaches, goals, drawbacks, and achievements of academic studies on optical communication and RoF systems. This analysis focuses on the field's problems and achievements. In summary, RoF technology integration of optical and wireless networks holds enormous potential to satisfy the changing needs of high-capacity, high-speed wireless communication. In order to effectively utilise the potential of RoF systems and progress contemporary wireless networks, additional study and development work is yet required.

Keywords:
Wireless Communication
Radio-over-Fiber
Modulation Techniques
Optical Filters
Optical Communication

INTRODUCTION

The development of wireless communication networks in the modern era requires ongoing capability improvement and the supply of wide benefits. Wireless networks are now widely used in both the military and the civilian worlds, and they are an essential part of our everyday lives. Our lifestyles have undergone tremendous transformation due to the swift progress of technology. The need for more bandwidth has increased due to the spread of communication technologies and the internet's quick development [1].

Wireless network programs like Global System for Mobile (GSM) and General Packet Radio Service (GPRS) were created in the early days of telecommunications with low data rates in mind. But as more and more people adopt next-generation mobile technologies and their need for bandwidth-intensive applications increases [2], systems that can effectively handle the large information rates expected in future wireless networks become more and more necessary. As a result, practical options such as radio-wave frequencies and optical fibers are being investigated. Even though optical fiber technologies provide much more bandwidth and longer transmission links, using radio-wave frequencies has benefits in the wireless domain and helps to alleviate spectral congestion.[3].
Moreover, it is hard to imagine contemporary living without the creative applications of wireless technology, such as artificial intelligence (AI), streaming high-definition video online, and cutting-edge consumer programs like YouTube that demand a lot of bandwidth. All of these applications need a lot of capacity, fast transmission rates, and low latency [4]. Therefore, high transmission speed, wide bandwidth, and dependable mobility have become prerequisites for today's wireless communication systems [5, 6].

Nevertheless, as the operational Radio Frequency (RF) spectrum experiences escalating congestion and maneuvering within the higher frequency band becomes progressively intricate, fulfilling these requirements directly proves challenging [7]. Two strategies have been identified to address these limitations. The first approach uses the idea of Micro/Pico cells, in which the size of the cell is lowered to support a higher number of subscribers [8]. The second option is to operate in a higher frequency band as an alternative to reducing spectral congestion in the lower frequency range [9]. Nevertheless, implementing these ideas comes with a number of difficulties. Reducing the size of a cell to serve more customers means that additional Base Stations (BSs) are needed to cover the whole service area, which raises the total cost [10].

However, choosing to operate at a greater frequency range results in increased costs for equipment, installation, and maintenance. In recent decades, optical fiber communication has become an essential part of communication systems, demonstrating its superiority as a vital transmission mechanism in contemporary telecommunication networks [11, 12].

As a result, choosing optical fiber over copper cables for wireless networks makes it easier to design new locations and greatly eases the actual deployment of equipment. Furthermore, the combination of wireless and optical networks provides benefits including improved physical security and resistance to fading [13]. The large amounts of data traffic, high data speeds, and large bandwidth requirements that are common in today's wireless communication networks can be effectively managed with this strategy. The suggested system architecture reduces system cost and complexity by using optical fiber as the transmission medium and implementing the complicated and expensive procedures at a Central Unit (CU) as opposed to the Base Station (BS)[14].

To cater to the burgeoning bandwidth requirements of individual users, the integration of optical and wireless networks is employed through a technique known as radio-over-fiber (RoF). RoF technology is presented as a viable and cost-effective solution to meet the escalating user bandwidth demands and wireless requirements in broadband, interactive, and multimedia wireless services. In RoF, an analog optical connection is utilized to convey information over optical fiber by transmitting modulated radiofrequency (RF) signals from the central station (CS) to the base station (BS) or remote antenna unit (RAU) [15]. The modulation process can take place either directly on the radio transmission or on an intermediary frequency. In simpler terms, RoF entails the conveyance of information through optical fiber by modulating light using a radio signal [16].

RoF can be used to set up a personal area network or high-speed wireless local area network. The particular applications dictate the frequency of radio signals transmitted by RoF systems, which varies greatly and usually falls within the GHz range [2]. Prior to being transmitted across the air in RoF systems, wireless signals are optically transferred between a Central Station (CS) and a group of Base Stations (BSs). The majority of signal processing duties, including as coding, multiplexing, RF generation, and modulation, are handled by the Central Office (CO), which increases the BS's cost-effectiveness. Every base station (BS) is set up to establish a radio link with a minimum of one user's mobile station that is within the BS's radio range. As a result, RoF is set to be a crucial technology in the years to come [17].

An extensive analysis of Radio over Fibre (RoF) technology and its incorporation into wireless networks of communication is presented in this research. It starts out by providing thorough explanations of RoF technology, including its underlying concepts, modulation methods, and technical nuances. This investigation highlights the main issues that modern wireless networks must deal with, namely spectral congestion and RF spectrum constraints. In order to properly manage data traffic, high speeds, and bandwidth requirements, the article suggests integrating optical fibre into wireless systems as a solution to these difficulties.

It explores the technical details of RoF systems in more detail, giving detailed explanations of modulation methods and the importance of optical filters. The study also performs a thorough evaluation and analysis of pertinent academic research, summarising findings, techniques, and advantages and disadvantages. Lastly, it identifies directions for further study and research with the goal of advancing RoF systems and contemporary wireless networks. All things considered, this work makes a substantial contribution to the field of wireless communication research by providing answers, recommendations, and new avenues for investigation into the integration of RoF technology.

2. RADIO OVER FIBER

The first uses of Radio over Fiber (RoF) occurred in mobile and cordless phone services in 1990. This technology differs greatly from the traditional optical fiber communication system in terms of implementation,
even if it may be able to address some of the issues with ultra-high-speed wireless systems for mobile communication. Radio over fiber technology has a wide range of possible applications, despite its underutilization [18, 19].

Different roles are involved in the coordination between the Base Station (BS) and the Central Station (CS). The CS is in charge of the creation of signals and modulation methods, using a transmitter that consists of a laser and a data source. Conversely, the BS, which has a receiver that is essentially made up of a photodiode, picks up signals from the Optical Fiber Network (OFN). The electrical signal is transformed into an optical signal inside the CS, which then uses OFN to link to the BSs. The OFN includes remote nodes that use demultiplexing to distribute the amplified optical signal to the base stations. The optical signal is converted back into the electrical domain for end-user delivery via a small antenna device called a remote antenna, which is housed in the base station (BS). The BS receives end-user radio signals, transforms them into the optical domain, and sends the data back to the CS via OFN all at the same time. The goal of this complex procedure is to improve the dispersion of radio frequency (RF) signals between control stations and base stations [20].

Long-distance transmission issues can be resolved by the optically linked system, especially in underserved areas and dead coverage areas like tunnels, where macro base stations frequently fail to provide sufficient coverage. By extending coverage to places where wireless signal transmission is impossible due to wave propagation characteristics, such as hilly terrains, subterranean spaces, tunnels, and isolated regions, the implementation of RoF technology becomes crucial in addressing dead zones [21]. Figure (1) shows Optical Communication Architectures: Exploring Radio-over-Fiber (RoF) Systems for Backhaul, Fronthaul, and Converged Access Networks.

When taking into account the baseband-to-modulated RF format function, the conversion of electrical signals to optical signals simplifies the integration and upgrading of signals with RoF. Even while copper coaxial and other conventional transmission media might not completely replace optical fiber, it is by far the most effective and useful option in situations where factors like system transparency, RF power loss, and future improvements are crucial. Even though RoF has a lot of potential, further research in this area is necessary before it can be used widely [23].

Direct modulation and external modulation are the two main types of modulation that are often used in RoF systems. The RF signal directly fluctuates in the direct modulation format in accordance with the semiconductor laser diode’s bias current. Conversely, external modulators that are fitted with Mach-Zehnder or electro-absorption interferometers are integrated for modulation functions [24].

3. MODULATION IN OPTICAL SYSTEM

In the fields of electronics and telecommunication, modulation is the process of changing one or more properties of cyclic waveforms by another signal, known as the modulation signal, is a standard procedure.
Effective information conveying frequently uses this modulation strategy. It's important to remember that, as shown in Figure (2), the carrier frequency must be at least twice that of the modulation signal. The figure shows several types of modulation.

These modulation methods can be categorized into two main groups:

### 3.1 Direct Modulation

Using this technique, the RF signal directly modulates the light source's brightness. The RF signal is then recovered by direct detection at the photodetector (PD). Known as intensity modulation direct detection (IMDD), this method is acknowledged as the most basic and economical way to optically transmit radio frequency signals. It is important to properly alter the RF signal before transmission. The photocurrent that is produced is a precise duplicate of the RF signal that is modulating; it is immediately obtained in the first phase following its passage through the fiber and its direct detection on a photodetector [26]. The optical signal received is subsequently transformed into an RF signal through the combined action of the photodetector (PD) and a band-pass amplifier located at the distant antenna position (as depicted in Figures 3). This method offers significant advantages as it is straightforward, robust, and cost-effective. Furthermore, when a low-dispersion fiber is employed alongside an external modulator, the system achieves linearity. Although the transmitter architecture is remarkably uncomplicated and economical, its performance is notably affected by shortcomings in laser modulation. In commercially available Radio-over-Fiber (RoF) systems, a laser diode undergoes direct microwave intensity modulation, catering to restricted RFs (typically up to 2 GHz), suitable for wireless services like Global System for Mobile Communication (GSM) and Universal Mobile Telecommunications System (UMTS). As such, one significant limitation of this technology is that it cannot operate efficiently at higher microwave frequencies. This limitation results from fading in the modulation sidebands caused by the laser diode's limited modulation bandwidth and the effect of fiber dispersion. To overcome this obstacle, sophisticated ultra-high-frequency optical analogue transmitters and receivers must be used in conjunction with accurate fiber dispersion compensation techniques (Figure 3) [27].

![Modulation tree](image1)

**Figure 2.** Modulation tree[25].

![Direct Modulation](image2)

**Figure 3.** Direct Modulation[28].
3.2 External Modulation

Out of all systems, optical external modulation (Figure 4) is a superb option for producing optical mm-wave signals with outstanding spectrum purity since it is a straightforward method of getting around the drawbacks of direct modulation. High radio frequency frequencies (over 10 GHz) are often used for external modulation. An external modulator modifies the laser light with an intermediate frequency (IF) or, in the most basic arrangement, a mm-wave tone, after a continuous wave (CW) laser [29]. While direct modulation is advantageous for cost-effective transmitters, it introduces challenges such as excessive chromatic dispersions and undesirable wavelength chirping, particularly at high speeds. Consequently, external modulation is favored. The Mach-Zehnder Modulator (MZM) is a preferred modulator, often referred to as an electrical-to-optical (EO) converter. Recent research in the MZM domain indicates its versatility beyond being a simple EO converter. It has the potential to serve purposes such as linearization and compensation for dispersion introduced as the signal traverses an optical path. Specially designed MZMs have emerged as solutions capable of addressing both of these issues simultaneously [30]. The limited switching speed and amplitude noise of the laser source.

For this kind of modulation, the best strategy to reduce unwanted effects is to move the modulation process away from the laser source and towards an interferometer-based arrangement, like the Mach-Zehnder interferometer (MZI). The MZI operates like a switch; signals with a value of 1 are accepted while those with a value of 0 are rejected. Choosing external modulation allows larger data rates than choosing intensity modulation. Furthermore, additional improvements can be achieved by adjusting the optical carrier’s phase and amplitude [31].

Before being transmitted, the laser source’s optical signal must be modified by adding signal information. Visual alteration is the term used to describe this process most often. The two primary types of systems that use this technology are external modulation systems and direct modulation systems. A digital signal with a bit range of up to one gigabit per second is directly correlated with the adjustment of an optical signal [32]. The refractive index difference can be adjusted to match the high optical frequencies used in lasers. However, there’s a chance that this modification will cause variations in the output mode and frequency. The operational current in the architectural designs needs to be kept as low as possible in order to exceed the chirp frequency. But minimizing the chirp frequency also lowers the extinction rate of the modulator, which lowers the signal-to-noise ratio [33].

![Figure 4. External Modulation](image)

4. OPTICAL FILTERS

An extensive summary of the different optical filters used in various applications may be found in the Table (1). The components, uses, and functionalities of each filter type are explained. In the domains of scientific study, imaging, and telecommunications, where exact control over light wavelengths is critical, an understanding of these many optical filters is vital. Fabry-Perot, Fiber-Bragg Grating, Tunable, Absorptive, Band Pass, Infrared, Ultraviolet, and Dichroic filters are among the filters that are covered. The purpose of this compilation is to provide experts and hobbyists in the fields of optics and allied fields with a reference manual.
Table 1. Different optical filters

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabry-Perot Filter</td>
<td>Also known as a “Thin-film filter,” it consists of two flat highly reflective mirrors spaced some distance apart, forming a Fabry-Perot interferometer. A light signal is incident on the left part of the interferometer. Some light passes through the cavity, some exits the cavity, and the remaining light is reflected[34].</td>
</tr>
<tr>
<td>Fiber-Bragg Grating Filter</td>
<td>An element of WDM systems, the Fiber Bragg Grating performs multiplexing and demultiplexing functions. When light passes through a grating, certain wavelengths interfere effectively, while others are destructively interfered with[35].</td>
</tr>
<tr>
<td>Tunable Filter</td>
<td>Utilizes two main technologies: MEMS and Bragg grating. Various types include liquid-crystal tunable filter, acousto-optics tunable filter, and linear variable filter. Applied in drug discovery, microplate readers, gemology, and other fields[36].</td>
</tr>
<tr>
<td>Absorptive Filter</td>
<td>Typically constructed from glass with added inorganic or organic compounds. These compounds absorb specific wavelengths of light and transmit others. Plastic can also be used to create a gel filter, which is lighter and more cost-effective than glass-based filters[37].</td>
</tr>
<tr>
<td>Band Pass Filter</td>
<td>Allows certain wavelengths to pass through while blocking others. The width of the band pass filter in the wavelength range is less than an angstrom and a few hundred nanometers. Combines LP and SP filter characteristics to block noise and optimize receiver sensitivity in single optical channel applications[38].</td>
</tr>
<tr>
<td>Infrared Filter</td>
<td>Infrared light covers a broader range of wavelengths than visible light, from 300 GHz to 430 THz. Used in infrared photography, metrology, thermography, and heating applications. Infrared is divided into near-infrared and far-infrared.</td>
</tr>
<tr>
<td>Ultraviolet Filter</td>
<td>Ultraviolet wavelengths range from 400 nm to 100 nm, subdivided into Ultraviolet A (400-315 nm), B (315-280 nm), and C (280-100 nm). UV filters, with RED, GREEN, and BLUE layers, are employed in diverse applications. Ultraviolet light is shorter than visible light but longer than X-rays[39].</td>
</tr>
<tr>
<td>Dichroic Filter</td>
<td>Transmits light based on wavelength; it allows light within a specific wavelength range to pass through while blocking light outside that range. Used for long pass and short pass applications, providing selective transmission of light[40].</td>
</tr>
</tbody>
</table>

5. ROF’S CHALLENGE IN 6G COMMUNICATION

The application of Sub-THz technology presents potential and challenges for 6G communication. Even though Sub-THz frequencies offer enormous data-rate transmission capacities, establishing dependable mobile user communication in deployment settings is fraught with difficulties. The propagation characteristics of Sub-THz signals present a significant difficulty since they are characterised by specular and sparse channels with dominant multipaths coming from reflections or line-of-sight (LOS). These difficulties are made even worse by diffraction and penetration losses. Although they are limited by existing technology restrictions, increasing broadcast power or improving receiver sensitivity are viable alternatives to guarantee sufficient signal-to-noise ratio (SNR) for Sub-THz communication[41].

Furthermore, in order to monitor prevailing propagation patterns, it becomes imperative to deploy high-gain and beam-steerable antennas at both the transmitter (Tx) and receiver (Rx) ends. However, obstacles like the lack of commercially available RoF units at Sub-THz frequencies and the difficulty of achieving phase coherence in measurements prevent the use of Radio over Fibre (RoF) schemes, which could address issues like long-range communication and frequency extension. These difficulties highlight how difficult it is to put RoF solutions for Sub-THz communication in 6G networks into practice [42].

6. RELATED WORKS

Table (2) summarizes key findings, methodologies, objectives/problems, weaknesses, and strengths from various scholarly works related to Radio over Fiber (RoF) systems and optical communication. Each row represents a specific study conducted by different authors, offering insights into diverse aspects of optical communication technology. The organized information allows for a comprehensive overview of the state of research in this field, highlighting both challenges and advancements. This table serves as a valuable resource for individuals interested in understanding the nuances of RoF systems, modulation techniques, and the impact of various factors on system performance.
Summary on RoF Technologies, Modulations, and Optical Filters: Review (Manea N. Obeid et al)

<table>
<thead>
<tr>
<th>Author</th>
<th>Key Findings</th>
<th>Methodology</th>
<th>Objectives/Problems</th>
<th>Weaknesses</th>
<th>Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hussein Ahmed Mahmood (2019) [43]</td>
<td>FBG improves performance</td>
<td>SCM/ASK, FBG</td>
<td>Chromatic dispersion impact</td>
<td>Specific fiber length of 10 km</td>
<td>Better performance observed</td>
</tr>
<tr>
<td>Musaddak M. Abdul Zahra (2022) [44]</td>
<td>128 QAM susceptibility</td>
<td>RoF-MMW, 50 Gb/s, 128 QAM</td>
<td>Ultra-high-capacity transmission</td>
<td>BER not favorable for 128 QAM</td>
<td>Successful long transmission</td>
</tr>
<tr>
<td>Oratilwe Jothi (2022) [45]</td>
<td>256-QAM outperforms 16-QAM</td>
<td>SCM-OFDM at 10 Gbps</td>
<td>Enhance system capacities</td>
<td>Lower performance for 16-QAM, 64-QAM</td>
<td>Useful combination of SCM and RoF</td>
</tr>
<tr>
<td>Abdul Nasser A. Abboud (2018) [46]</td>
<td>Dispersion limits high bit rate</td>
<td>OFDM with 16-QAM</td>
<td>High bit rate over long haul</td>
<td>Dispersion problem limits bit rate</td>
<td>Successful 20 Gbps transmission</td>
</tr>
<tr>
<td>Muhammad Usman Hadi (2019) [47]</td>
<td>D-RoF cost-effective</td>
<td>Bandpass sampling for 20 MHz LTE</td>
<td>Mitigate impairments in A-RoF</td>
<td>Cost of deploying D-RoF system</td>
<td>Supports transmission up to 70 km</td>
</tr>
<tr>
<td>Namita Kathpal (2018) [48]</td>
<td>MDRZ &amp; CSRZ reduce signal degradation</td>
<td>Non-linear distortion in optical system</td>
<td>Non-linear distortion in optical system</td>
<td>Rapid Q-factor decrease for MDRZ &amp; CSRZ</td>
<td>Enhances data transmission up to 100 Gbps</td>
</tr>
<tr>
<td>Humam Hussien (2021) [49]</td>
<td>ISI in fiber due to non-linearities</td>
<td>DFSK with NRZ modulation</td>
<td>Growing demand for high data rates</td>
<td>ISI in previous architecture</td>
<td>Good results for different signals</td>
</tr>
<tr>
<td>Paramjot Singh (2018) [50]</td>
<td>CSRZ modulation technique at 3.2 attenuation</td>
<td>FSO based ROF-WDM system</td>
<td>High Q factor with low BER</td>
<td>CSRZ modulation at 3.2 attenuation</td>
<td>Suitable for topographical areas</td>
</tr>
<tr>
<td>Hussein Ahmed Mahmood (2018) [35]</td>
<td>Distortion with increased fiber length</td>
<td>RoF with DPSK modulation, WDM, ideal dispersion FBG</td>
<td>Efficient technique for baseband signal detection</td>
<td>Distortion with increased fiber length</td>
<td>Best performance with ideal dispersion FBG</td>
</tr>
<tr>
<td>Dr. Adnan Hussein Ali (2020) [51]</td>
<td>Limited dynamic range in optical-OFDM systems</td>
<td>ODSB modulation with 16-DWDM-ROF link</td>
<td>Limited non-linearities in optical communication fibers</td>
<td>Limited dynamic range in optical-OFDM systems</td>
<td>Better performance with ODSB modulation</td>
</tr>
<tr>
<td>Marwah M. Kareem (2021) [22]</td>
<td>BER increases with fiber length</td>
<td>OFDM-RoF with 16-QAM modulation</td>
<td>Identifying minimum BER for 16-QAM modulation</td>
<td>BER increases with fiber length</td>
<td>Achieves fiber length of about 100 km</td>
</tr>
<tr>
<td>Honglin Ji (2020) [52]</td>
<td>D-RoF vs. A-RoF spectral efficiency</td>
<td>Theoretical analysis and experimental confirmation</td>
<td>Comparison of spectral efficiency between D-RoF and A-RoF</td>
<td>D-RoF considered low spectral efficiency</td>
<td>D-RoF offers exponential improvement in SNR</td>
</tr>
<tr>
<td>Badiaa Ait Ahmed (2019) [53]</td>
<td>Constraints on wavelength channel spacing</td>
<td>WDM RoF with FBG, EDFA, DPSK</td>
<td>Resolution of nonlinearity effects, signal loss, dispersion</td>
<td>Constraints on wavelength channel spacing</td>
<td>Good enhancement with DPSK in WDM RoF</td>
</tr>
<tr>
<td>Haoyu Yu (2022) [54]</td>
<td>NLIs and PAPRIs in RoF-based CN</td>
<td>Full-duplex RoF-based CN with WDM A-RoF 5G mm-wave system with LMS equalization</td>
<td>Minimization of NLIs and PAPRIs</td>
<td>Prominent factors minimized</td>
<td>NLIs and PAPRIs minimized in model</td>
</tr>
<tr>
<td>Umar Farooq (2021) [55]</td>
<td>Chromatic dispersion affecting OFDM subcarriers</td>
<td>8/32 RoF-BF with Bessel Filter</td>
<td>Equalization for OFDM subcarriers affected by chromatic dispersion</td>
<td>Chromatic dispersion affecting OFDM subcarriers</td>
<td>Equalization achieved communication distances</td>
</tr>
<tr>
<td>Namita Kathpal (2020) [56]</td>
<td>Non-linear effects in RoF system</td>
<td>Reduction of FWM effect with Bessel Filter</td>
<td>Non-linear effects, specifically FWM</td>
<td>Non-linear effects, specifically FWM</td>
<td>FWM sideband power decreased by 4 dBm</td>
</tr>
<tr>
<td>Drissa Kamissoko (2020) [57]</td>
<td>ODSB scheme limited to 30 km fiber length</td>
<td>Optical heterodyning with ODSB and OSSB schemes</td>
<td>Power fading effect due to interference and fiber CD</td>
<td>ODSB limited to 30 km fiber length</td>
<td>Supports up to 120 Gbps data rates over long distance</td>
</tr>
<tr>
<td>Rawa Muayad Mahmood (2022) [58]</td>
<td>Phase noise effect on DWDM-RoF system</td>
<td>Effect of phase noise on mm-wave signal</td>
<td>Phase noise effect on DWDM-RoF system</td>
<td>Phase noise effect on DWDM-RoF system</td>
<td>Controlled phase imbalance reduces phase noise</td>
</tr>
<tr>
<td>Haleema Khalil (2021) [59]</td>
<td>BER at large distances approaches 1</td>
<td>Choosing efficient modulation format for data transfer</td>
<td>BER at large distances approaches 1</td>
<td>BER at large distances approaches 1</td>
<td>NRZ performs well with high quality factors</td>
</tr>
<tr>
<td>Fabio Barros de Sousa (2021) [60]</td>
<td>Long-distance RoF communication</td>
<td>Design and investigation of RoF system</td>
<td>Long-distance RoF communication</td>
<td>Long-distance RoF communication</td>
<td>Excellent BER and Q-factor values</td>
</tr>
</tbody>
</table>
An examination of related studies in Radio over Fibre (RoF) technology demonstrates a wide variety of conclusions, approaches, advantages, and disadvantages. Principal discoveries encompass enhancements in efficacy via methodologies such as Fibre Bragg Grating (FBG), observations of modulation susceptibility like 128 QAM, and juxtapositions of modulation schemes like 256-QAM and 16-QAM. Methodologies encompassing topics including signal modulation, dispersion, and signal processing techniques span from theoretical analyses to experimental confirmations. While improvements in modulation efficiency, cost-effectiveness, and transmission capacity are among these studies' strong points, their drawbacks frequently centre on restrictions on system performance or particular modulation techniques. All things considered, these studies offer insightful information about how to best optimise RoF systems for different applications, underscoring the significance of further study in this area to solve current problems and enhance network capabilities.

7. CONCLUSIONS
This study explores the complex field of Radio over Fibre (RoF) technology and how it is essential to contemporary wireless networks. It starts by explaining the growing needs of our technologically advanced society for bandwidth and dependable mobility. RF spectrum restrictions and spectral congestion provide issues that can be addressed by the development of RoF technology. The discussion includes modulation strategies used in optical systems, highlighting the differences between external and direct modulation approaches, each of which has pros and cons of its own. Moreover, the importance of optical filters in regulating light wavelengths is emphasised, providing an understanding of their various uses in the fields of science, imaging, and telecommunication. After that, the story changes to focus on how 6G connectivity is developing and emphasises the advantages and disadvantages of Sub-THz technology. Last but not least, the synthesis of related works offers a thorough summary of significant discoveries and methodology in the field, opening the door to additional research and development in optical communication and RoF systems. Radio over Fibre (RoF) technology can be made even more advanced in the future by incorporating it into wireless communication networks, implementing sophisticated signal processing in the optical domain, integrating it with 6G communication systems, reducing the size of RoF transceivers, improving security and energy efficiency, and supporting standardisation initiatives for smooth integration with wireless standards.

REFERENCES

IJEEI, Vol. 12, No. 1, March 2024: 245 – 254
Summary on RoF Technologies, Modulations, and Optical Filters: Review (Manea N. Obeid et al)


