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Broadband Subcarrier Signals Based on AWG-RoF Network: A Software Simulation

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Keywords:
Radio-over-fiber; AWG; Last-mile; Future mobile system; MIMO.

Highlights:

- AWG-based broadband subcarrier over RoF enhanced capacity and increased the number of users.
- Reduce latency in many applications like real-time communications.
- Flexibility deployment with various broadband and mobile communications.
- Support for emerging technologies for 5G and future wireless networks.
- Combining AWG and RoF is an attractive scheme for future increasing in data demands and ensuring sustainability of broadband services.

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Abstract: Radio-over-fiber is emerging as a progressively significant technology within the wireless in-building market. Identifying dynamic range requirements and determining the optimal laser option is crucial for this particular application. Hence, this study introduces a revolutionary architecture for the array waveguide grating multiplexer (AWG) that utilizes switched radio over fiber technology, offering significant system design, installation, and operation advantages. Prospective developments encompass applying AWG-RoF conveyance to facilitate expected pivotal technologies for future mobile systems, including millimeter-wave transmission and enormous MIMO. The output power ranged between (19.983dBm) and (12.431dBm), the average received noise power (dBm) was (17.117), and the average received power was (17.2425dBm). The simulation demonstrated favorable outcomes, including enhanced bandwidth and transmission range, while experiencing negligible losses.

محاكاة برمجية لإشارات الموجة الحاملة الفرعية ذات النطاق العريض بناءاً على شبكة الراديو عبر الالياف وشبكة الدليل الموجي

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الخلاصة

تبرز تقنية الراديو عبر الألياف كتقنية ذات أهمية متزايدة في سوق الاتصالات اللاسلكية داخل المباني ويعد تحديد متطلبات النطاق الديناميكي وتحديد خيار الليزر الأمثل أمراً بالغ الأهمية لهذا التطبيق بالذات. فضلاً عن ذلك، تقدم هذه الدراسة بنية مناسبة لمضاعف شبكة الدليل الموجي الذي يستخدم تقنية تحويل الراديو عبر الألياف، مما يوفر مزايا كبيرة في تصميم النظام وتركيبه وتشغيله. وتشمل التطورات المحتملة تطبيق نقل الراديو عبر الالياف- شبكة الدليل الموجي لتسهيل التقنيات المحورية المتوقعة للأنظمة المتنقلة المستقبلية، بما في ذلك نقل الموجات المليمترية وشبكات (متعدد الادخال-متعدد الاخراج) السريعة التطور. وان متوسط الطاقة الناتجة يتراوح بين (12.431dBm) و(19.983dBm) ومتوسط طاقة الضوضاء المستلمة (12.431dBm) ومتوسط الطاقة المستلمة (17.2425dBm). وأظهرت المحاكاة نتائج واعدة بما يتناسب مع زيادة عرض النطاق ومسافة النقل بأقل الخسائر.

الكلمات الدالة: الراديو عبر الالياف، شبكة الدليل الموجي، الميل الاخير، انظمة الموبايل المتنقلة، متعدد الادخال-متعدد الاخراج.

1.INTRODUCTION

When enormous amounts of data are transmitted over long distances via optical fiber transmission links (OFTL), nonlinear impairments (NLIs) are caused by the channel, and distortions are caused by the modules of the system [1,2] in addition to restricting the maximum. Regarding the data rate that can be conveyed via the system, these possessions impede the long-term transmission distances. While fronthaul networks have a transmission range of at most 20 kilometers, in the presence of the application of intermediate frequency (IF) or high bandwidth signals, such deficiencies remain to be debated [3]. RoF can provide an auspicious resolution for the unification of radio signals and substantial methodology for economical and high-capacity broadcasts [4-7]. This conveyance system merits prohibition, wireless transmission of enormous capacity at a low cost owing to its straightforward design and low medium distortion, anti-interference, enormous bandwidth, and small power consumption [8,9]. Additionally, flexibility and adaptability coincide with the collective network's expansion [10]. The moveable system sector is predominantly influenced by digital data transmission for an extended period via the long-term evolution (LTE) of the fourth generation (4G) optical fiber network, its resistance to chromatic defects, nonlinearity phenomenon, and adverse dispersion consequences. Utilizing RoF conveyance reduces the radio access unit (RAU) cost by omitting the need for digital-to-analog converters (DACs); however, it necessitates low sampling rates for transporting enormous signals with bandwidth. Transporting the same cargo volume via RoF technology necessitates significantly reduced data rates. Therefore, it is a prospective contender for forthcoming 5G networks. Constructing RoF in implementing wavelength division multiplexing (WDM) systems holds promise for augmenting. Incorporating advanced modulation formats, such as quadrature amplitude, significantly enhances fidelity. By microwave signals for quadrature amplitude modulation (QAM), the objective is to increase the capacity for data rate and propagation path [11-13].

2.RELATED WORKS

As a general solution for enhancing the resistance of the communication network to forward-thinking NLIs, RoF equipment is utilized. However, the industry requires an ultra-reliable network for 5G mobile systems. This field exhibits substantial research potential owing to the manifold benefits of RoF transport, which facilitates the development of the optimized structure and meets the current capacity demands while overcoming NLIs. An overview of recent developments in this field is provided below. RoF transport for transmitting millimeter-wave signals for 5G has recently been investigated as a framework [14]. Zakrzewski [15] investigated a dynamic RoF for the subsequent generation of RAN in pursuit of compensating NLIs. Coelho and Salgado [16] investigated the Orthogonal frequency division multiplexing (OFDM)-enabled MIMO and waveform of signal intermixing noise after RoF transport. The WDM-RoF network was examined in [17] with a fixed input voltage and 0.4 nm channel spacing during focusing. Data stream transmission was performed across a variety of optical fiber lengths. The RoF gearbox system was defined in [18]. The authors discussed using multimode operation to transmit optical comb signals over multiple wavelengths. In such systems, the inter-modal noise associated with RoF transmission is identical based on the signal transmission. Agoua et al. [19] inspected the D-band millimeters. The wave propagation and generation scheme was done by utilizing quadrature modulators (QMs). These two modulators function by inhibiting the optical carrier, generating two couples of twin spread spectrum (SS) signals in the primary mode. A digital multi-service RoF framework for an impartial host [20] described a fronthaul link that utilizes multiband multiplexing. Umezawa et al. [21] illustrated an S-band RoF transmission system by employing multiple input, OFDM, and bi-orthogonal multi-input multi-output (MIMO) wavelets. The optimization process in [22] observed signal handling arrangements for the uplink and downlink of a RAN design, providing wireless connection customers with nonlinear energy harvesting. In the same way, Paredes-Páliz et al. [23] labeled a complete RoF scheme in terms of a coherent integration-based broadband network. Li et al. [24] investigated the beamforming of MIMO with user adaption. Ayoob et al. [25] demonstrated a hybrid optical signal amplification system that includes Raman scattering and an Erbium-doped fiber amplifier (EDFA) simulated to take advantage of the amplification properties of the optical signal transmitted through the optical fiber network. The output power signal is adopted efficiently. Miladic et al. [26] demonstrated the optical technologies that could help smart cities use sensors and reliable optical infrastructure. Boubakri et al. [27] determined the relation between the 5G networks based on the optical networks to applications in smart cities.

3.AIMS AND SIGNIFICANT CONTRIBUTIONS

The present paper mainly aims to present a hybrid system based on AWG-RoF created to improve the overall system's efficacy and sustain the existing high-volume requirements. The primary objective is to minimize nonlinearity problems and attain an optimized state. The primary contributions of this paper are outlined as follows:

1- Optical transmission of high-order NLIs and linear dispersions (LDs) accumulate over extended distances. However, an AWG-RoF grid is still necessary to meet future cellular networks' substantial transportation volume requirements. This study investigates to compensate for a high-datarate WDM system.

2- System factors, including received power, input power, and communication fiber length, are utilized to assess the suggested scheme's efficacy.

3- The bitrate consideration is utilized to calculate the reliability of the AWG-RoF model under consideration.

The subsequent sections of this paper are structured as follows: Section 4 illustrates the AWG-RoF technology, and Section 5 describes the model outline, surveyed by a prototypical explanation. Section 5 summarizes the system's analysis results. Lastly, the conclusion is presented in Section 6.

4.THE AWG-RoF TECHNOLOGY

Arrayed waveguide gratings (AWGs) are commonly used as optical (de)multiplexers in wavelength division multiplexed (WDM) systems. These devices can multiplex a large number of wavelengths into a single optical fiber, thereby considerably increasing the transmission capacity of optical networks. The devices are based on a fundamental principle of optics that light waves of different wavelengths interfere linearly with each other. In other words, if each channel in an optical communication network uses light of a slightly different wavelength, then the light from many of these channels can be carried by a single optical fiber with negligible crosstalk between the channels. The AWGs are used to multiplex channels of several wavelengths onto a single optical fiber at the transmission end and are also used as demultiplexers to retrieve individual channels of different wavelengths at the receiving end of an optical communication network. Figure 1 illustrates the AWG structure.

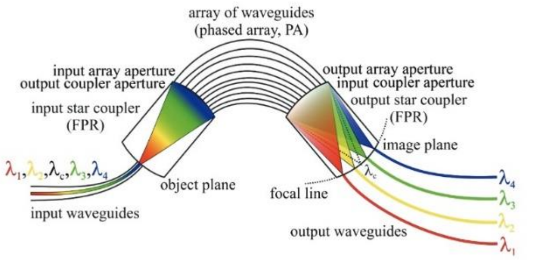

Fig. 1 The AWG MUX-De-MUX Scheme.

RoF transmissions can be used for multiple purposes, such as television distribution in the access network and inside the home or the transport of cellular signals between a base station and remote antennas. In fact, this technology allows information to be transported over long distances at a low cost and with high performance. The RoF technology aims to increase the radio range seamlessly to cover the last-mile area, as shown in Fig. 2.

Fig. 2 The RoF Technology.

5.MODEL SUGGESTED DESIGN

This article examines the (AWG-RoF) conveyance system with the objective of nonlinearities suppression. The enhanced capacity and long-range RoF network depend on how well the nonlinearities phenomenon is administered. As a backbone, a hybrid model consisting of single-mode fiber (SMF) and multimode fiber (MMF) is utilized in this system to transmit the RF waves comprising polarization mode dispersion (PMD) and group velocity dispersion (GVD) in addition to amplified spontaneous emission (ASE). This article discusses the context of pulse width reduction by applying advanced implementation of modulation schemes, filters, and amplifiers. This paper mainly aims to describe an AWG-RoF link resistant to distortion through utilizing sophisticated modulation formats to accommodate various transmission types. The distances range from one kilometer to ten kilometers of fiber, with low input power demands and high receiver sensitivity. The schematic diagrams for the current proposal are demonstrated in Fig. 3. The main layout of the AWG-RoF network has three subsystems: Transmitter, Channel, and Receiver, as illustrated in Figs. (4-6). The primary characteristic of the AWG-RoF system is economical because it eliminates the requirement for high-frequency. The digital-to-analog conversion (ADC) is at the desired radio frequency (RF), up-conversion of the baseband signal to that frequency. The remote antenna unit performs DAC or the central unit. The Optisystem software [28], a widely recognized simulation instrument for optical fiber analysis, is utilized to construct the model infrastructures for communication. Many library elements are available in an Optisystem environment, including RF and optical components, based on their characteristics and values in the actual world. The RF signals are generated in the microwave by four types (S1, S2, S3, and S4) with frequencies of (56MHz, 116MHz, 176MHz, and 186MHz) generated using the sine generator, respectively. Consequently, the continuous laser was used to create an optical signal of (193.1THz) and power of (0dBm). Meanwhile, each subcarrier was modulated over the phase modulator. Regarding using AWG, a number of these optical signals from various clients are combined. A MUX conveys all channels through a single-mode fiber and a multimode fiber (SMF/MMF) connection. To compensate for the propagation and insertion losses of AWG, an erbium-doped fiber amplifier (EDFA) was used, which additionally aids in eliminating a fraction of the amplified unplanned radiation caused by the filtration process. At the output of the device, an Avalanche photodiode (APD) was affixed to execute the optical-to-electrical (O/E) procedure. EDFA is one in which the optical signal is changed directly to the RF frequency using the AWG-RoF conveyance. Consequently, the recovered RF signal at the receiver is at the wanted RF, from which it can subsequently be transferred to the vacuum of space. For additional noise elimination by filter process, the main parameter properties are listed in Table 1.

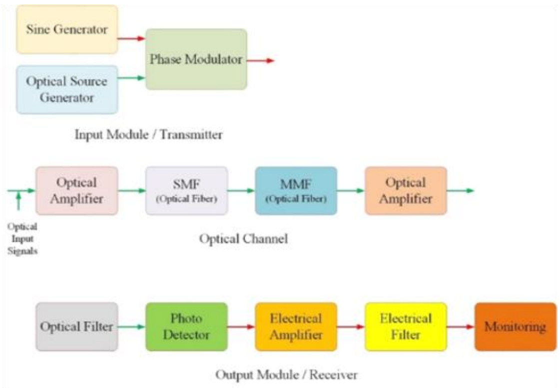

Fig. 3 The AWG-RoF Block Diagram for Three Modules.

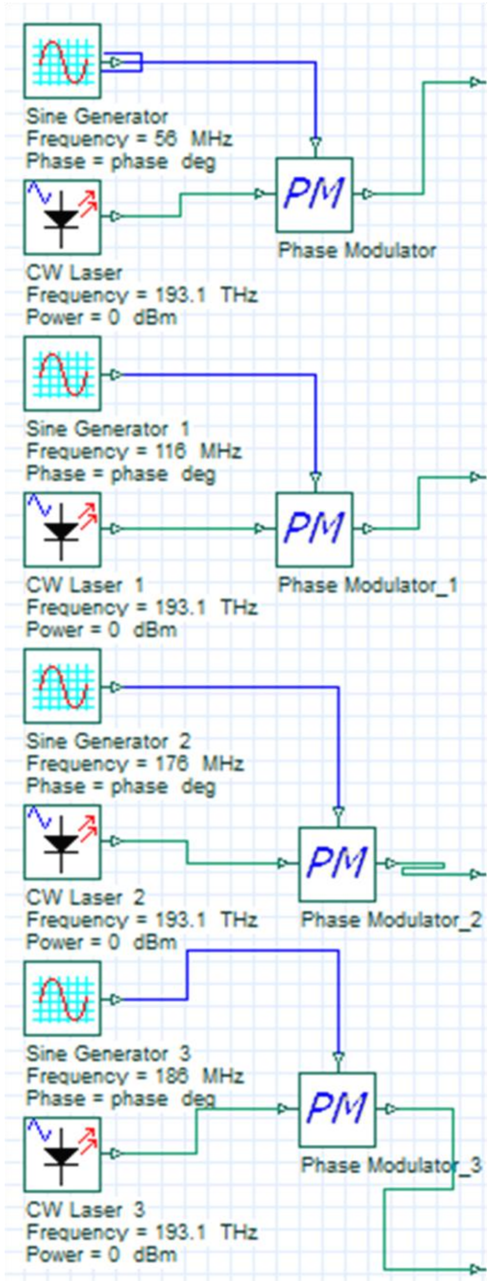

Fig. 4 The AWG-RoF Optical Transmitter Subsystem.

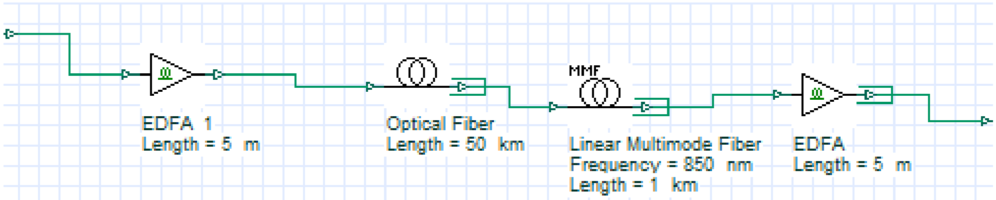

Fig. 5 The AWG-RoF Optical Transmission Hybrid Channel Subsystem.

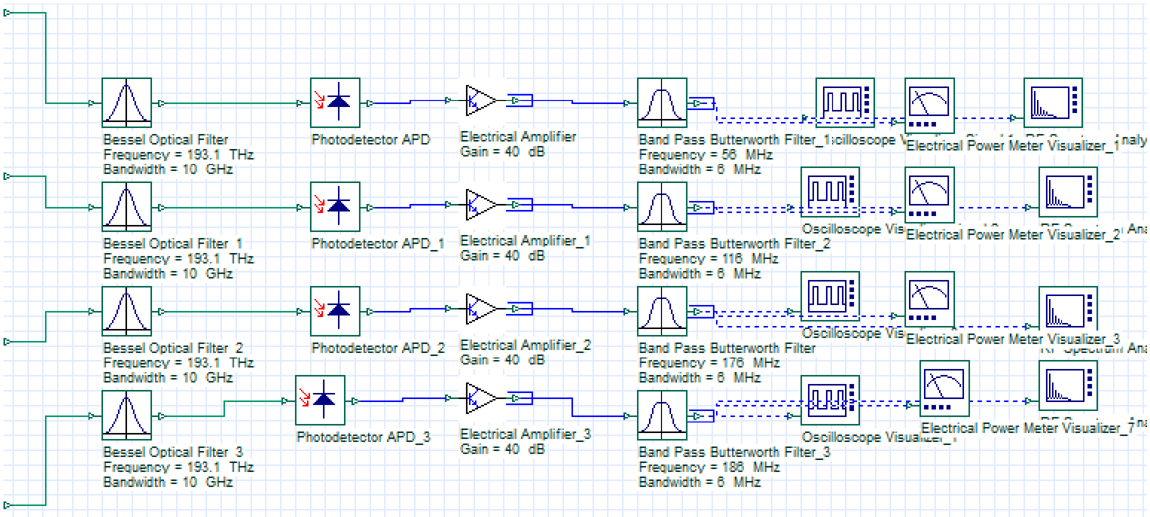

Fig. 6 The AWG-RoF Receiver Subsystem.

Table 1 Elements, Notations and Magnitudes Utilized in this Proposal.

Parameter	SMF Distance	SMF Attenuation	SMF Dispersion	SMF Dispersion Slope	SMF Effective Area	MMF Distance	MMF Attenuation	MMF Dispersion	Bitrate	Sample per bit	Sequence Length	Number of Samples	EDFA Noise Bandwidth
Value	50	0.2	17	0.075	80	1	2.61	-100	2.5	128	128	16384	13
Unit	km	dB/km	ps/nm/km	ps/nm²/km	um²	km	dB/km	ps/nm/km	Gbps	-	-	sample	THz

The next step is to assess and analyze the worth of the received signals, the electrical power meter visualizer, oscilloscope visualizer, and the RF spectrum analyzer utility provided by Ref. [28] through recalculating reamplified, restyling, and timing signal by the receiver segment. Furthermore, this step offers a robust integration to process signal processing and implement receiver-side equalizers based on a custom model.

6.DISCUSSION AND RESULTS

The systematic prototype presented in Section 3 illustrates how the proposed system mitigates the impact of subcarriers on the AWG-RoF system. The proposed model investigated 4-subcarriers for an alternative set of parameters. The results of these subcarriers over the hybrid link with (10Gbps) of datarate are shown in Figs. (4–6). To simulate the outcomes concerning the transmitted length, input power, and received power and to assess the sensitivity of the receiver against a flexible system, an EDFA was employed to generate a spectrum of received power spanning between (19.983dBm) and (12.431dBm), as determined by an optical power meter (Figs. 7 –10); however, the average of received noise power (dBm) was (17.117). As shown in these figures, the relationship between amplitude and time from one side, and the other side was the relationship between power and frequency. The results considered were more significant. Furthermore, the results indicated that achieving the proposed solution enables the attainment of an equivalent with high-datarate for the last mile of transmission based on the AWG-RoF architecture.

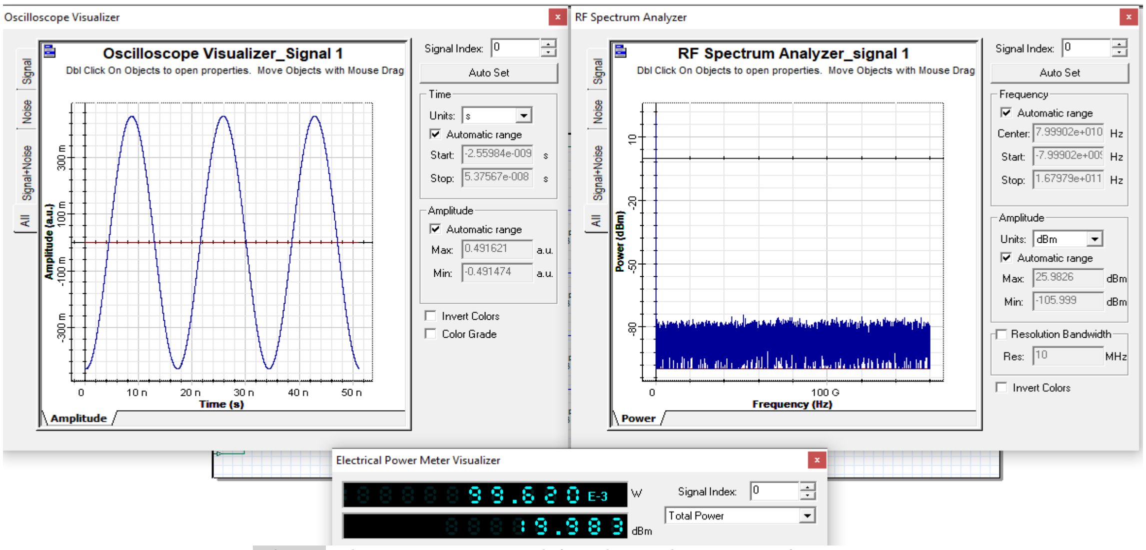

Fig. 7 The Output Signal for the Subcarrier of 56MHz.

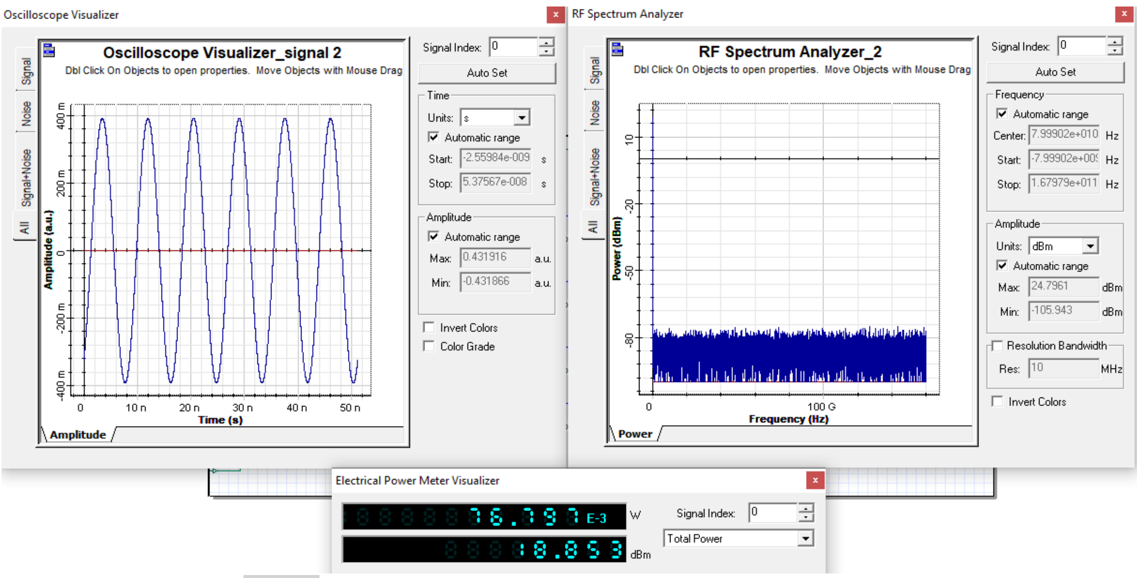

Fig. 8 The Output Signal for the Subcarrier of 116MHz.

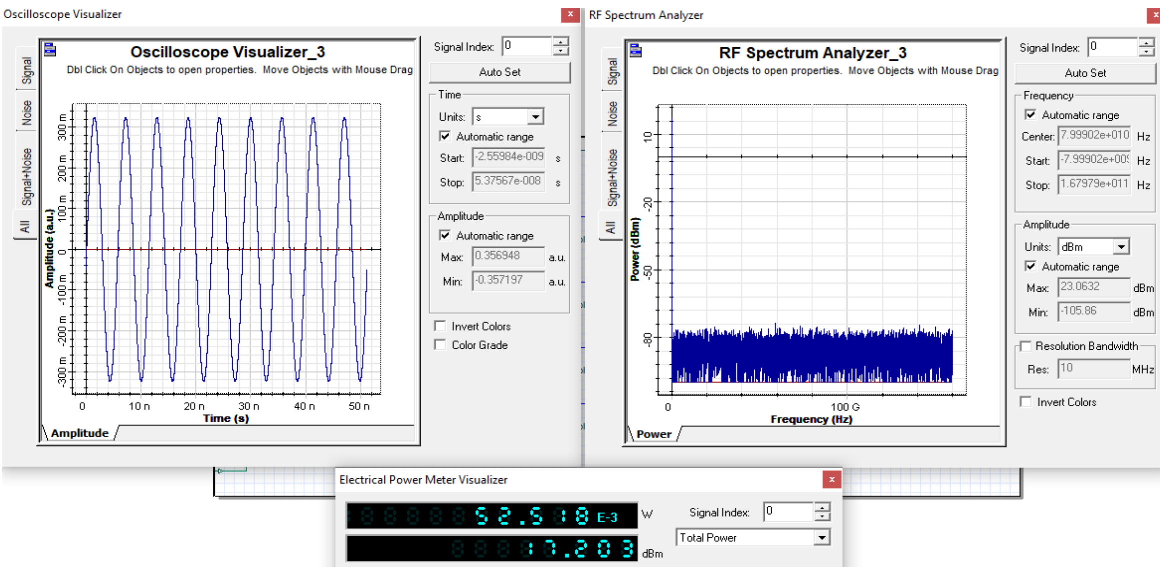

Fig. 9 The Output Signal for the Subcarrier of 176MHz.

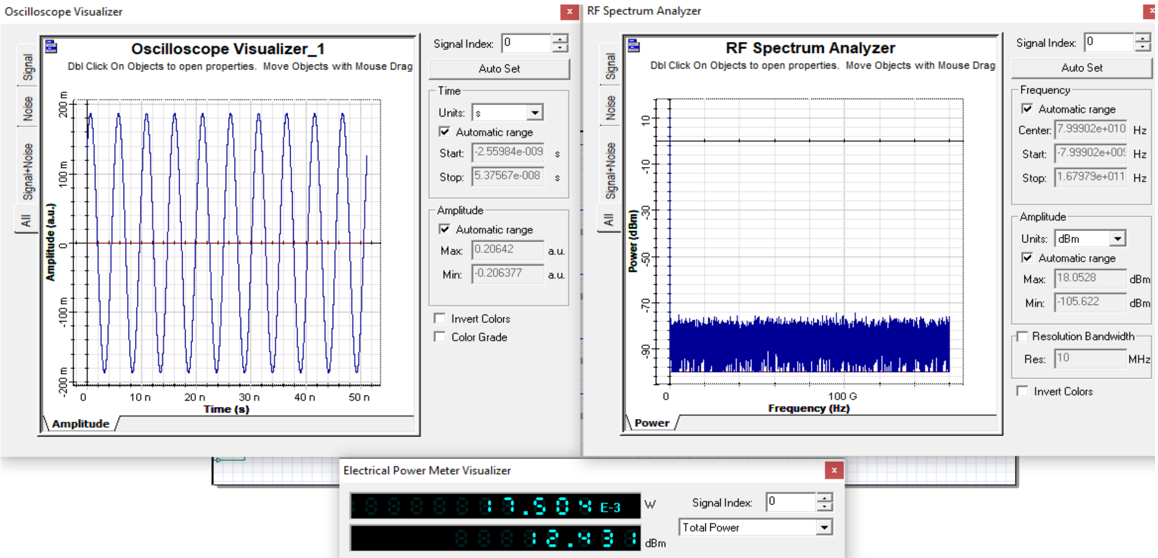

Fig. 10 The Output Signal for the Subcarrier of 186MHz.

The main limitation facing radio-over-fiber systems is how to exploit the current infrastructure used by the Ministry of Communications in Iraq without changing it. Through this proposal, the researchers put a road map to overcome this limitation with the best bitrate and multi-users. Compared with [6, 15,17], this proposal used a hybrid link-based AWG-RoF system with a high bitrate.

7.FINAL REMARKS

The AWG-RoF networks are the primary obstacles. The renowned RoF transmission performance limiting factors, including the RF signals, were examined and managed according to the model presented. For a distance of (51) kilometers, the average received power was (17.2425dBm). A maximum of 4-channels was used to demonstrate the performance enhancement created by suppressing NLIs. Moreover, LDs were utilized in the proposed system for the fronthaul networks with high capacity. There are prospective developments encompassing applying AWG-RoF conveyance to facilitate the expected pivotal technologies for future mobile systems, including millimeter-wave transmission and enormous MIMO.

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