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PAPER

# Multi-Access Techniques Comparison for Remote Lab System

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**ABSTRACT**

Remote lab systems are one of the essential requirements for an increased academic productivity in the modern digital world. These systems support and facilitate effective migration from face-to-face classroom education to online education. Digital technology applications and processes are required to easily build a remote lab system. With the availability of multiple access techniques, users can comfortably share laboratory equipment among themselves. The sharing of resources using the remote lab system is highly required for a smooth deployment and implementation of online education. This paper therefore proposed and tested some techniques that combine Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) in remote lab systems. The tested techniques are Multi-Carrier Direct Sequence CDMA (MC-DS-CDMA), Multi-Tone CDMA (MT-CDMA), Multi-Carrier CDMA (MC-CDMA), and Spread Spectrum Multi-Carrier Multiple Access (SS-MC-MA). The first step proposed in this work had to do with the setting of the comparison criteria. At the second step, the solutions cited previously in the real equipment was tested and the best option that met the criteria was selected for the eLab system since the performance technique varies with the laboratory equipment characteristic. The four techniques that were tested demonstrated high performance in telecommunications and online laboratory systems. The implementation of these techniques will benefit universities in several ways, which include reduction of remote lab cost and optimization of sharing of online resources among users. This will further provide students with conducive learning environment by addressing the challenges of reservation and time slot limit. It is therefore recommended that MC-CDMA should be integrated into remote lab system.

**KEYWORDS**

remote lab, multiple access, OFDM/CDMA, e-learning

## 1 INTRODUCTION

The COVID-19 pandemic led to lockdown of business enterprises and schools which prompted governments to impose online learning to curtail the spread

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of the disease. Switching to online education was very easy for some courses. However, implementing online education is very complicated for practical works. Technological advancement enables specialists to build remote lab systems. There are two kinds of remote laboratories: firstly, the remote laboratory that is based on simulation, and secondly, the remote laboratory that enables students and teachers to directly manipulate the laboratory equipment.

A remote lab could be used to enhance e-learning system which helps to facilitate full online education. Based on the foregoing, some previous works on remote lab system were reviewed. The challenge facing remote lab constructor is the possibility of letting multiple users manipulate the practical work equipment at the same time to yield a good performance. Pablo et al. investigated the possibility of opening the existing laboratory for public system. The findings of the study revealed a new approach that described a remote laboratory that supports external specifications like mobile device [1].

Ian Grout in [2,3] defines a new concept for building remote lab which was dedicated for both specialty, electrical and information engineering disciplines. The study [3] provided a full list of reported an operational remote lab named WebLab-Deusto that was developed by the University of Deusto. However, in the researchers' university, they exploited the concept by Gout [3] to develop the remote lab system as presented in this study.

The specialist in remote lab system has a challenge of possible manipulation of the laboratory's equipment at the same time. Elmissaoui et al. studied and tested Time Division Multiple Access TDMA technique in remote lab system to allow for multiple students to remotely use the lab equipment at the same time [4]. This paper proposed the need to give a time slot for each user so that the system will not be interrupted by other users. The solution given by [4] enables the researchers to allow 3 students to manipulate the lab equipment simultaneously.

The simultaneous multiple access to the system by students enables us to avoid the reservation process. This solution shows that the proposed remote lab is available everywhere in real time. Currently, different methods tend to emerge to give rise to new techniques that combine carrier modulation and spectrum spreading (OFDM and CDMA). These combinations induce multiple techniques dedicated to multiple access systems like MC-DS-CDMA, MT-CDMA, MC-CDMA, SS-MC-MA etc. In the present work, good capacity is needed to separate users from these techniques. The module is used to connect to the internet, and the laboratory equipment can take the base transceiver station (BTS) in the GSM system.

In this paper, we proposed and tested multiple techniques to give the chance for multiple students to manipulate the laboratory equipment at the same time without interruption. This paper started by introducing the general concept of the remote lab system. The second part presented some techniques that combine OFDM and CDMA. In the third section, comparison techniques were introduced. Furthermore, the four techniques in the experimental laboratory were also tested and compared.

## 2 KAIROUAN UNIVERSITY REMOTE LAB SYSTEM E-LAB PRESENTATION

Moving from being present physically in class to e-Learning system is the priority of the university of Kairouan. To build a full online education, the remote lab became an essential necessity. The eLab system can provide online resources for students to do their practical work using the internet without moving to a physical laboratory building. There are multiple solutions required to connect to the lab equipment remotely. Firstly, the remote desktop solution was used, with each equipment being connected to the personal computer (PC) in the laboratory. Secondly, a module like Raspberry Pi that enables us to connect the equipment lab to the internet network was also used. For the internet to be used, each lab equipment must have a port connection that enables the PC or the Raspberry Pi chip to maintain connections and specific execute commands or instructions in required formats. The two techniques cited above were adopted in the University of Kairouan to ensure a proper connection to the remote lab equipment. The remote lab is available for students' use anywhere anytime at their own pace. For practical works, students need to use only a connected equipment like mobile phone, Tablet, PC etc. In fact, to use the lab equipment, students are not obliged to install anything and can have only a simple navigator and remote lab computer parameters. Each lecturer must follow the necessary scenario of the practical work. Also, students can feel the same condition as the physical presence and can use each lab equipment remotely. Multiple equipment such as switcher, Raspberry Pi, camera, oscilloscope etc. were used to build the remote lab. The switcher was used to switch between multiple practical scenarios. The Raspberry Pi module was used to ensure internet connection of each equipment. The camera was installed so that students can view the lab materials in real time. On the other hand, the oscilloscope helped in the visualization of the network signal. To enhance the online laboratory, a new tool that is used to exploit the user's feedback was developed. The concept of this tool is published in [5,11]. The University's laboratory equipment is available online and can be accessed using a VPN application that allows for the creation of a private data tunnel. This solution allows for reinforcement of the security procedures of the online laboratory system.

The eLab is a laboratory dedicated to the design and assembly of remote practical work. The creation of this laboratory took place after the participation of the University of Kairouan in two European projects within the framework of the TEMPUS and Erasmus+ programs, the EOLES project and the e-LIVES project. This eLab project aims to centralize the equipment acquired within the framework of the two European projects in a single secure laboratory to facilitate the design and creation of practical works that can be manipulated remotely 24 hours a day, 7 days a week. Figure 1 shows Kairouan University eLab developed under e-LIVES and EOLES projects. The components of the eLab system are briefly described as follows.

### 2.1 eLab equipment

- **Servers:** A Web server was specially designed for e-learning which makes it possible to host and monitor the results of online training modules. Organizations that have LMS can contact the administrator to find out how to upload their modules in the server.
- **TPs:** Practical Electronics presents theoretical concepts on electronic components (AOP, resistors, diodes, capacitors, transistors, etc.) as well as more elaborate operating principles of remote electronic systems.
- **Oscilloscopes:** Oscilloscopes are used for troubleshooting or repairing electronic equipment. They are basically used to draw graphs of electrical signals coming directly from the electronic equipment or through a transducer.

- **LPKF ProMat E44:** ProtoMats provide a low-cost introduction to the world of professional in-house PCB prototyping.

### 2.2 eLab software

- **Moodle:** This software is probably one of the most used in this field. It can be used by a single teacher to share course materials or serve several thousand students in a university.
- **LabVIEW:** This server runs LabVIEW and LabVIEW virtual instruments as well as the LabVIEW web server. Data acquisition device was used for this application.
- **Audacity:** This sound processing software allows users to modify existing audio files (sound enhancement, noise removal, equalization, addition of silences or effects, audio editing, etc.). It supports WAV, AIFF and MP3 file formats.
- **ProMax VE:** This is a complete open-source platform for enterprise virtualization. With the built-in web interface, users can easily manage virtual machines and containers, software-defined storage and networking, high availability clustering, and multiple out-of-the-box tools on a single solution.


**Fig. 1.** Kairouan university eLab

## 3 MULTI-ACCESS TECHNIQUES

### 3.1 MT-CDMA

The MT-CDMA technique combines OFDM and Sequence Spread-Spectrum (DSSS) modulation. The most characteristic of this technique is to ensure using multi sub-carriers [6,7,10]. The spreading process is done in the time domain [8].

Figure 2 represents the MT-CDMA transceiver. The Signal to Noise plus Interference Ration (SNIR) for the jth user can be written using the following formula [6]:

$$SNIR = \frac{1}{\frac{1}{T_b}\int_0^{T_b}\left[\sum_{n=1}^{j-1} m_n \times \left(\sum_{L=1}^{GMT} C_L^n \times \sum_{L=1}^{GMT} C_L^j\right) \times \left(1 + cos2\pi(f_{c_i} - f_{c_{i+1}})t\right)\right]dt + N_{O_n}} \quad (1)$$

Where $f_{c_i}$ and $f_{c_{i+1}}$ are the frequencies of different orthogonal sub-carriers, $N_{O_n}$ is the thermal noise for nth user, ***GMT*** is the number rake combiners, $m_n(t)$ is the user digital data stream, $T_b$ is the bit period, $L$ is the code length, and $C_L^n$ and $C_L^j$ are the specific codes.

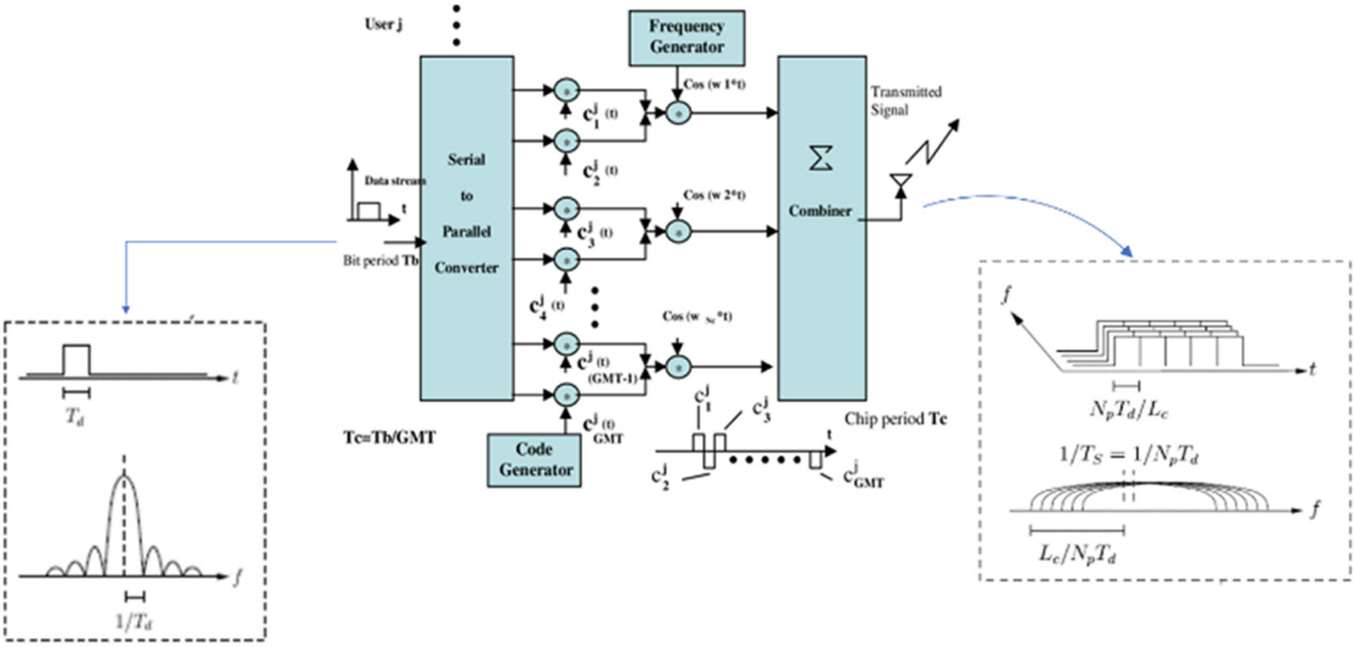


**Fig. 2.** MT-CDMA transceiver architecture [6]

## 3.2 MC-CDMA

This technique is used for the spreading step is made in the frequency domain. A unique code is available and assigned to each user. At the receiver, we exploited the dispreading by the specific code to ensure users' separation. Moreover, MC-CDMA can allow multi-users to have access to eLab application at the same time with a good performance compared to MT-CDMA [6]. Figure 3 shows the MC-CDMA transceiver architecture. The SNIR of this system can be presented as:

$$SNIR = \frac{\sum_1^{N_c} \frac{A_c^2}{2}}{\sum_1^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + N_{O_n}} \quad (2)$$

Where $A_c^2$ is the magnitude of the single carrier, $N_c$ is number of subcarriers, and ***GMC*** is the generate multi carrier.

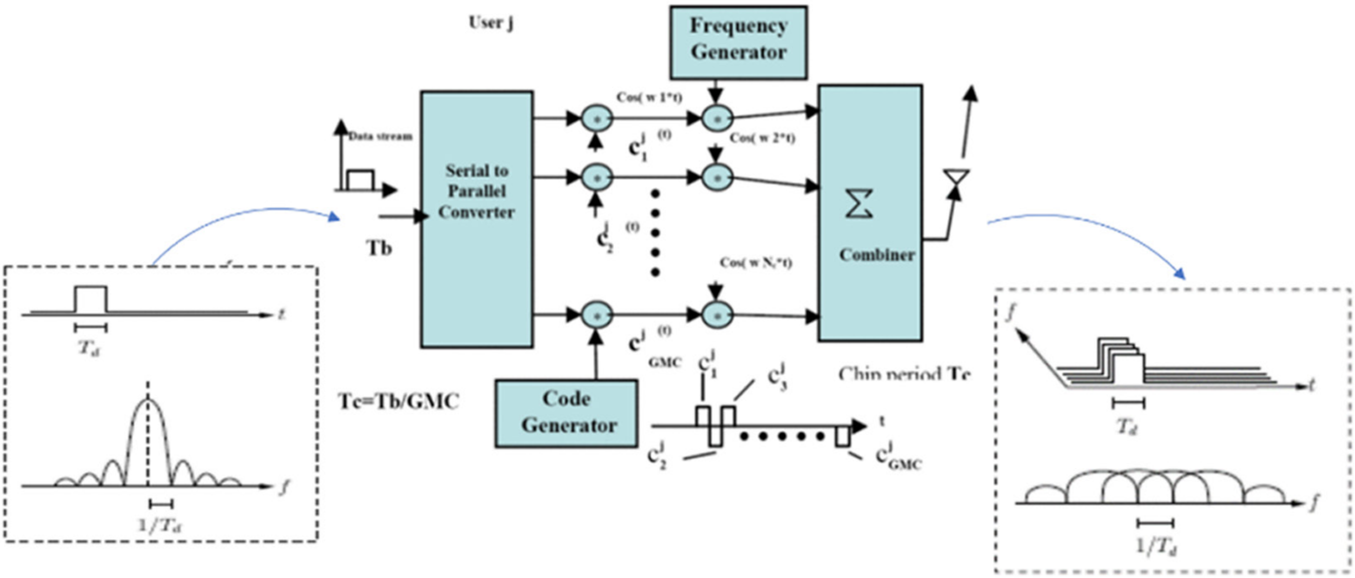


**Fig. 3.** MC-CDMA transceiver architecture [6]

### 3.3 MC-DS-CDMA

To ensure users' separation, we exploited the same technique as MC-CDMA. The data spreading is done in the time domain with a code assigned to each user and transmitting the information over several orthogonal frequencies [9]. Figure 4 illustrates the MC-DS-CDMA transceiver architecture. The SNIR for this technique is presented below [7]

$$SNIR = \frac{1}{\frac{1}{T_b}\int_0^{T_b}\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t)dt + N_{O_n}} \quad (3)$$

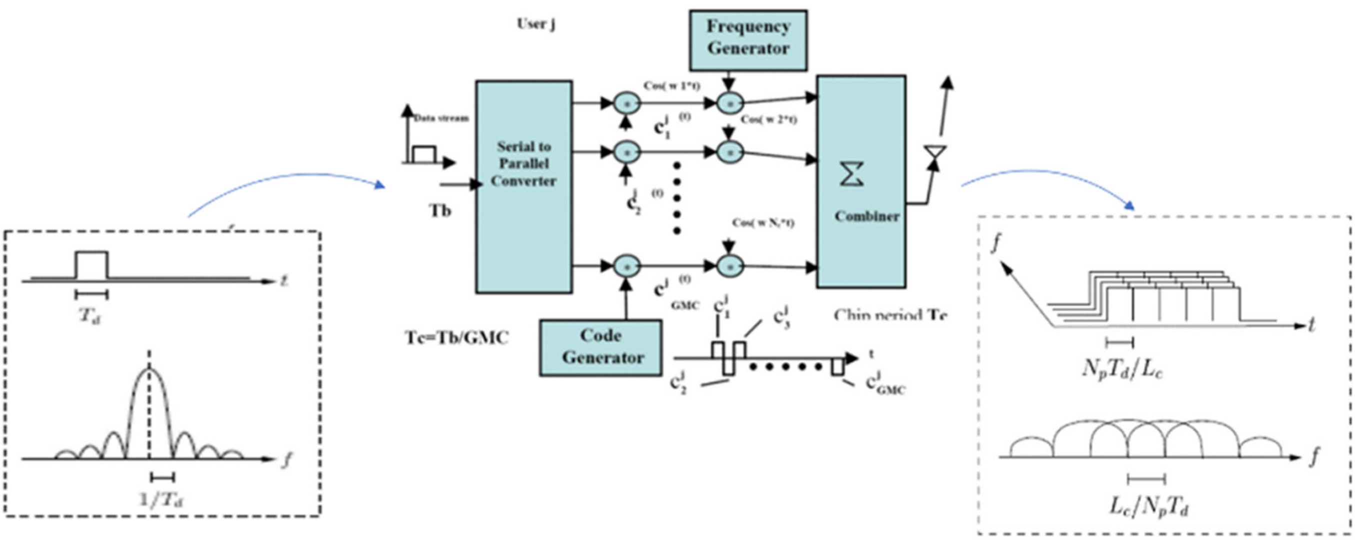


**Fig. 4.** MC-DS-CDMA transceiver architecture [6]

### 3.4 SS-MC-MA

SS-MC-MA is a more vital way of spreading range and multi-transporter regulations. S. Kaiser et al. presents this strategy [14,15], which is gotten from MC-CDMA framework. This strategy joins various accesses by appropriating numerous codes and access through recurrence division. Every client can send information on a subset of subcarriers by exploiting the entrance dispersion products of spreading codes. Figure 4 addresses the SS-MC-MA modulator for a jth client on account of an uplink with various Nseq groupings accessible inside a similar code family which is equivalent to the length Lc of the codes. SS-MC-MA frameworks have a few similarities with MC-CDMA frameworks, for example, the addition of the gatekeeper stretch to stay away from the peculiarity obstruction between images. In addition, these procedures additionally have contrasts. It should be noted that the framework SS-MC-MA impedance between clients doesn't exist since the information of a similar client are conveyed by a particular subset of subcarriers. Yet, there is the issue of obstruction between images of a similar client.

## 4 EVALUATION OF EXISTING REMOTE LAB

The current framework utilized a detailing arrangement instrument called MSRT. The Moodle study announcing apparatus (MSRT) is an independent application created to make reports situated in Moodle stage review. The initial step of this device is to plan the essential survey for students and instructors. The assessment of these two entertainers streamlines the researcher's work and the distant research facility framework. The survey relies upon the e-learning stage, likewise the expansion of poll to e-learning stage [5]. The application (modules) was introduced in the stage leading to creation of reports. The improvement of a metric application for Remote Lab, an adaptable device, is expected to separate pertinent information from surveys. Therefore, the following are the detailing instruments created: Ergonomic connection point, Rapid reportage, Modular apparatus, among others. The current framework presents measurement tools that empower clients to make the indicative of the distant lab framework. Nedic et al. [12] gave a record of NetLab from the University of South Australia, which aims at addressing the ordinary concerns of distant exploration places. With an arrangement similar to past undertakings, NetLab unites a grouping of lab equipment and even allows for joint exertion between understudies. The paper assumes that while the far away lab course of action didn't straightforwardly beat standard certified labs, the makers propose a mix of authentic and distant labs generally through the preparation of an instructive arrangement. In [13], *Gurkan* presented a far-off lab for an optical circuits course. The strategy used in this office is to at first familiarize the understudies with the thoughts at a basic level of optical communications. The pre-labs contain a heading video generated from lab frameworks on-line. This work similarly conducts assessment of the learning results and the teaching strategies. Here, the understudy's partner is the specialist using a Web-based customer for connection points with the LabView Web Server.

## 5 MULTI-ACCESS TECHNIQUES, COMPARISON AND RESULTS

Kairouan university built a full remote lab system under the **EOLES** and **e-LIVES** projects. The institution's laboratory is available for use by both students and lecturers. So far, there are five working practical works like RLC, operational amplificatory, robotic hand etc. The performance of the school's remote lab enables for the testing of multiple technologies.

After presenting various techniques, we interpreted the results provided by our application according to the parameters by varying the number of carriers and the number of symbols per carrier. Then, we compared the mixed techniques. After having presented the various techniques combining the multi-carrier modulations and spread spectrum, a comparison of key features and performance is offered in this section. To simplify this comparison, we have grouped the different parameters of MC-CDMA, MT-CDMA, MC-DS-CDMA techniques, and SS-MC-MA, as shown in Table 1. All these parameters are expressed in function of Td, the symbol duration after the binary coding of the signal. The addition of the guard interval is necessary in some technical cases like MC-CDMA and MC-DS-CDMA and l SS-MC-MA. However, it is not useful in the case of the MT-CDMA technique. In the case of an identical spectral occupation at full load, the four techniques make it possible to transmit the same bit rate symbol per user at $1/T_d$. We therefore found that the symbol rate per user and the spectral occupation are identical. Their differences lie in combining data from different users. Over a duration $T_d$, we noticed that the signal including Lc replicas of the same data $d_j$ on multiple subcarriers, where the diversity branches are said to be in frequency. On the other hand, for MC-DS-CDMA systems and MT-CDMA, the transmitted data was different on each subcarrier. The absence of redundancy in the information does not allow exploitation of the frequency diversity of the channel. However, since spectrum spreading is achieved in the time domain, it is possible to benefit from the channel time diversity. Regarding the SS-MC-MA technique, it only uses frequency diversity. In the case of an identical number of sub-carriers, the MC-CDMA technique exploits channel frequency diversity better than other techniques. The comparisons of these four techniques carried out in the literature on downlink give advantage to the MC-CDMA technology. This turns out to offer an excellent performance/complexity ratio, while achieving good spectral efficiencies, on downlink, which is one of the requirements of future multimedia networks. In addition, these comparisons show that multi-carrier systems offer one of the best results, better than single-carrier systems. During the implementation of these four techniques, we have noticed that the implementation of the MC-CDMA method is easier to implement than the other three. Indeed, this technique performs the spectrum spreading of the data than the OFDM modulation, which greatly simplifies the task. Figure 5 presents the results that illustrate the performance of the four previous techniques. With the help of these results, the MC-CDMA technique is found to be the most efficient. This was the reason for choosing the MC-CDMA technique for this study, especially for its excellent performance and complexity. Figure 6 shows the electronics' materials used in this work.

The comparison based on SNIR realized in [6] between these techniques was found to be analogous to our practical results. Multiple works in the literature like the simulation done in [6] further confirm our results.

**Table 1.** Comparison parameters

| Parameter | Value |
|---|---|
| Number of users | 3 |
| Number of carriers | $N_p = 64$ |
| IFFT size | 64 |
| Number of symbols per carrier | $N_{sf} = 16$ |
| Number of bits per OFDM symbol | $B_{ps} = \log2(M)$ |
| Basic modulation order | M = 16 |
| Guard time | $T_g = 4$ |
| Guard interval type | Adds 1 |
| Spreading code length | $L_c = N_p = 64$ |

The combination of technologies known as Internet of Thing (IoT) enhances proactive decision-making without human intervention [16]. The remote lab concept and feasibility varies with discipline. In fact, each practical work has its own characteristics and scenarios. In some specialties like chemical and mechanical fields, it's not easy to find the necessary scenarios and the equipment to build remote practical work. Furthermore, in other specialties, the presence of the students inside the laboratory is needed for some interventions. The implementation cost of some remote practical works is very high. For this reason, it will be better to look for a method to share the laboratory equipment between multiple users at the same time. This solution is still not applicable to all practical works, and it depends on time response equipment. According to our study, equipment sharing is valuable for remote practical work that has a time response of less than 450ms.

The virtual reality technology can enable students to understand the main concept that is being delivered [17]. For this reason, we proposed to use the virtual reality technology to implement some complicated remote practical works [18].

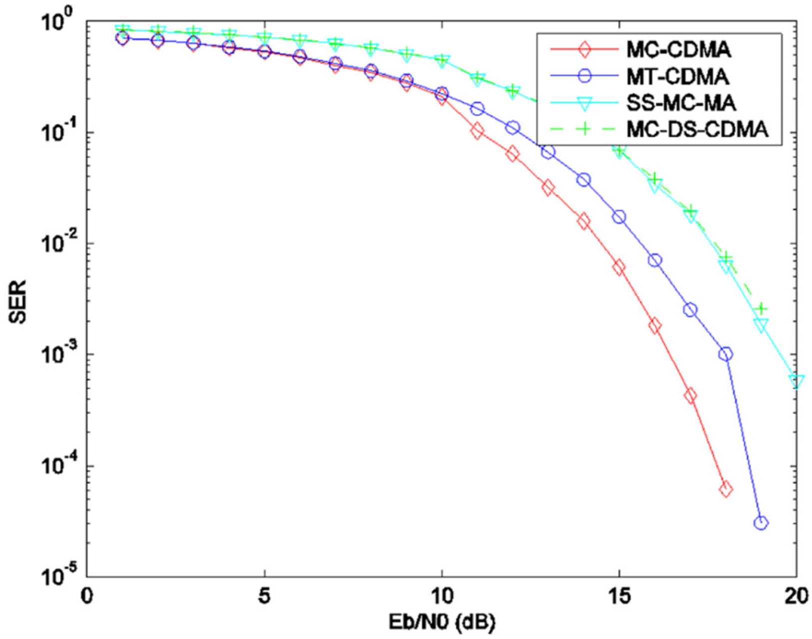


**Fig. 5.** OFDM/CDMA mixed system performance

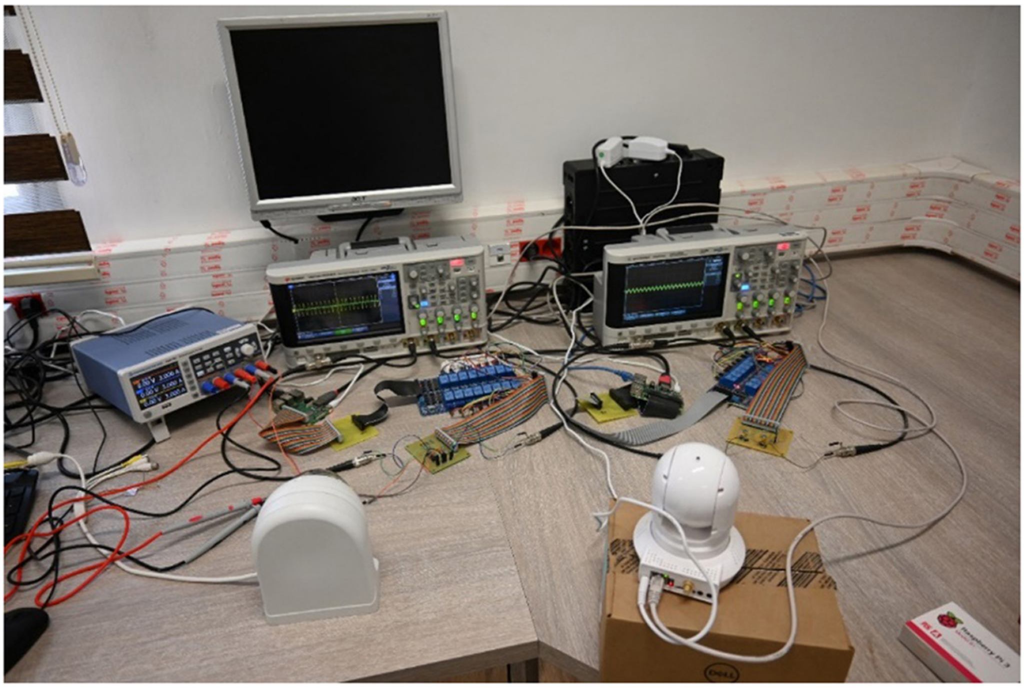

**Fig. 6.** Kairouan university eLab equipment

## 6 CONCLUSION

Due to the switching from physical lab attendance for practical sessions to e-Learning system, the implementation of a remote lab system became a necessity to solve the disruptions of academic activities caused by COVID-19 to ensure a full online education. In this paper, we proposed and tested four techniques that combine CDMA and OFDM. These techniques enabled us to remotely allow multiple students' access to the lab equipment at the same time. Also, these solutions make it easier to address the user's separation. The test of these techniques helps in recommending the use of MC-CDMA in the eLab system for remote education. Because MC-CDMA presents a good performance compared to other techniques, there is a need to use a module like Raspberry Pi that can take the role of BTS in GSM system, to implement the eLab system. The remote lab is operational for three users at the same time. This decision helps to ensure the stability and the service quality of the remote lab system. Based on the outcomes of this study, future works should be based on the development and testing of a new solution for chemical and mechanical remote labs.

## 7 REFERENCES

[1] Pablo Orduña, Danilo Garbi Zutin, Sten Govaerts, Irene Lequerica Zorrozua, Philip H. Bailey, Elio Sancristobal, Salzmann, Luis Rodriguez-Gil, Kimberly DeLong, Denis Gillet, Manuel Castro, Diego López-de-Ipiña, and Javier García-Zubia, "*An Extensible Architecture for the Integration of Remote and Virtual Laboratories in Public Learning Tools*", IEEE Revista Iberoamericana de Tecnologias del Aprendizaje (Volume: 10, Issue: 4, Nov. 2015). https://doi.org/10.1109/RITA.2015.2486338

[2] Ian Grout, "*Remote laboratories to support electrical and information engineering (EIE) laboratory access for students with disabilities*", IEEE, 2014 25th EAEEIE Annual Conference (EAEEIE), 30 May-1 June 2014. https://doi.org/10.1109/EAEEIE.2014.6879377

[3] Ian Grout, "*Remote laboratories as a means to widen participation in STEM education*", Educ. Sci. 7(4), p. 85, 2017. https://doi.org/10.3390/educsci7040085

[4] T. Elmissaoui, "Time division multiple access for remote lab (TDMA-RL)", International Journal of Online and Biomedical Engineering (iJOE), 18(07), pp. 4–13, 2022. https://doi.org/10.3991/ijoe.v18i07.29773

[5] Elmissaoui Taoufik, Charradi Sahbi, and Selim Wafik, "*Quality Assurance for Remote-lab Systems by New Reporting Tool*", Rev 2021; 18th International Conference on Remote Engineering and virtual Instrumentation, Hong Kong, February 24–26-2021: pp. 341–348.

[6] Saimoon Ara Amin, Mahbubul Alam Rafel, and S.P. Majumder, "*Performance Analysis of Multi-carrier DS-CDMA wireless*", 2009 Third UKSim European Symposium on Computer Modeling and Simulation.

[7] L. Vandendrope, "*Multitone direct sequence CDMA system in an indoor wireless environment*", Proc. of IEEE first symposium of communications and vehicular technology in the Benelux, Delft, The Netherlands, 1993, pp. 4.1-.1-4.1.8.

[8] A. Chouly, A. Brajal, and S. Jourdan, "*Orthogonal multi carrier techniques applied to direct sequence spread spectrum CDMA systems*", Proc. of IEEE GLOBECOM'93, Houston, USA, 1993, p.1723.

[9] S. Kondo and L. B. Milstein, et al., "*On the use of multicarrier direct sequence spread spectrum systems*", Military Communications Conference, pages 52–56, October 1993.

[10] M. Crussiere, J.-Y. Baudais, and J.-F. Hèlard, "*Robust and high-bit rate communications over PLC channels: A bitloading multi-carrier spread-spectrum solution*", in Proceedings of the 9th International Symposium on Power Line Communications and Its Applications (ISPLC '05), pp. 37–41, Vancouver, Canada, April 2005. https://doi.org/10.1109/ISPLC.2005.1430461

[11] Elmissaoui Taoufik , Agbo, Jonathan Chukwunwike, Onyedeke Obinna Cyril, Olayiwola Abisola Ayomide, Uzo Blessing Chimezie, Ikedilo Obiora Emeka, and Oluwatobi Adedamola Ayilar, "*Emotion Metric Detection By Machine Learning For ELearning System*", Elementary Education Online, (Volume: 20, Issue: 2), pp. 1832–1843, 2021. https://doi.org/ilkonline.2021.02.200

[12] Nedic, Machotka, and Nafalski, "*Remote laboratories versus virtual and real laboratories*", Frontiers in Education (FIE 2003) 33rd Annual, 2003.

[13] Gurkan, Mickelson, and Benhaddou, "*Remote laboratories for optical Circuits*", IEEE Transactions on Education, 2008.

[14] S. Kaiser and K. Fazel, "*A flexible spread-spectrum multicarrier multiple-access system for multi-media applications*", in Proc. IEEE Int. Symp. on Personal, Indoor and Mobile Radio Commun. (PIMRC'97), pp. 100–104, 1997.

[15] S. Kaiser and W. A. Krzymien, "*Performance effects of the uplink asynchronism in a spread spectrum multicarrier multiple access system*", European Transactions on Telecommunications (ETT), 10, pp. 399–406, 1999. https://doi.org/10.1002/ett.4460100409

[16] S. Nourildean and Y. A. Mohammed, "*IoT based wireless sensor network improvement against jammers using ad-hoc routing protocols*", International Journal of Interactive Mobile Technologies (iJIM), 17(07), pp. 133–147, 2023. https://doi.org/10.3991/ijim.v17i07.38587

[17] Reyad Alsalameen, L. Almazaydeh, Bilal Alqudah, and K. Elleithy, "*Information technology students' perceptions toward using virtual reality technology for educational purposes*", International Journal of Interactive Mobile Technologies (iJIM), 17(07), pp. 148–166, 2023. https://doi.org/10.3991/ijim.v17i07.37211

[18] R. Badarudin, D. Hariyanto, E. Supriyadi, I. W. Djatmiko, , M. B. Triyono, G. K. Kassymova and U. Urazaliyeva, "*Virtual laboratory application of direct current electric motor: An expert-based evaluation*", International Journal of Online and Biomedical Engineering (iJOE), 19(04), pp. 4–21, 2023. https://doi.org/10.3991/ijoe.v19i04.36749

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