Software Defined Radio (SDR) for Healthcare Applications: A Proposed Approach

B. Siva Kumar Reddy, N.L. Pratap

Abstract*: Recently, most of the hospitals are using conventional computer systems and medical equipment to diagnosis the patients. Moreover, healthcare services are mainly depending on the information technology, sometimes such dependency may cause network failure and that may result a loss of life. Therefore, in my contribution a smart architecture based on software defined radio (SDR) is proposed. This paper describes the proposed system in which three hospitals (SDR units), 9 patients are assumed at several distances from the hospital and they will try to communicate with the hospital. This system includes the integration of wireless communication concepts, wireless sensor networks, cloud technology and wireless medical devices on single common platform for seamless interoperability and reconfigurability. The proposed system is tested experimentally by using Universal Software Radio Peripheral (USRP) N210 as hardware platform and GNU Radio as software. This paper presented experimental results in terms of channel noise, signal to noise ratio (SNR), bit error rate (BER) and throughput. This paper concludes that the SDR is an emerging technology in healthcare applications with 24hr/365day business.

***Index Terms*: AGC, Cognitive radio, GNU Radio, Software defined radio (SDR), USRP.**

I. INTRODUCTION

Recently, the majority of communication among human to human, human to device and device to device became wireless due to its flexibility. The advantages of wireless communication over wired communication are presented in [1]. However, the application of wireless communication and signal processing to get improved performance in health care and biomedical infrastructures became a major challenging goal of the researchers. In 1961, Brody et al., proposed multi polar current singularities to represent the electrical behavior of heart and postulated the concept of an ideal electrocardiographic lead field [2]. Paul et al., proposed a method for measuring dipole parameters such as magnitude, location and direction of isolated hearts and muscles application to Frog Gastrocnemius [3]. Before applying the concept of communication to the medical applications, the cells of the human body is digitized and stored in the memory of a computer. Various methods are proposed in the literature to intercommunicate these cells such as ad hoc approach, the curvature of boundary segments, the non Euclidean coordinate approach etc [4]. In addition, different telemedicine networks are presented by showing the transformation of cells from one network to another [5] and recent trends in wireless networks [6].

In 1996, the first endoscopic telemanipulator using robotics systems is developed [7]. In 1997, a World Wide Web-based medical collaboration environment, WebOnCOLL designed virtual workspaces to offer integrated services such as email, annotations (a natural way for people to interact with multimedia content) and online collaboration [8]. Pavlopoulos et al., developed a novel emergency telemedicine system based on wireless communication technology AMBULANCE to provide tele-diagnosis, tele-consultation of mobile healthcare providers and long distance support [9]. A European Union (EU)-financed maritime tele-medicine project, MERMAID, is proposed to provide healthcare services via Integrated Services Digital Network (ISDN)-based video conferencing [10]. In 1998, emerging imaging sensor technologies are developed by considering multimedia imaging detector and molecular bio-electromagnetics from aerospace to healthcare [11]. Xiaohui et al, introduced the concept of artificial intelligence (AI) components that include machine learning for eye diseases [12]. A new wireless near-infrared energy system for medical implants is developed in which the status of the patient is transferred electronically using infrared rays [13].

The RITHME intercommunication platform was proposed to provide several communication functions between remote patients with physicians and the movements of patients in the hospital as well as outside of the hospital was possible [14]. D. Feng et al., presented recent advancements in the information technology for biomedical functional imaging [15]. Providing continues monitoring on remote patients became challenging, therefore, high compression technologies are proposed to transmit audio and video via Internet [16]. In 2001, W.G. Scanlon et al., analyzed the usage of numerical electromagnetic modeling techniques such as finite-difference time-domain (FDTD) to design bodyworn antennas and presented results in terms of wireless personal-area networking applications and biomedical signaling for 2/spl middot/45 GHz, 916/spl middot/5 MHz and 418 MHz [17]. In 2002, bacteria responsible for ENT and eye infections are classified using the Cyranose system and two experiments are performed [18]. Arnon et al., presented a comparative study of wireless communication network configurations such as Code-division multiple access (CDMA), slotted ALOHA (a multiple access protocol at the datalink layer),

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***** Correspondence Author
B. Siva Kumar Reddy*, Department of Electronics and Communication Engineering, Koneru Lakshmaiah Educational Foundation, Guntur (dt), Andhra Pradesh, India-522502.
N.L. Pratap, [1]Assistant Professor, Department of Electronics and Communication Engineering, KL Deemed University, Guntur (dt), Andhra Pradesh, India-522502.

over ALOHA, polling, and Carrier-sense multiple access (CSMA) for medical applications [19]. A decision support system tool for healthcare technology assessments is proposed using the analytic hierarchy process (AHP) methodology and the operations research/operations management (OR/OM) methodology [20]. Jian et al., designed a warning tool to detect Blood leakage during dialysis therapy based on fog computing with array photocell sensors and hetero-associative memory model [21].

Conventional wired/wireless communication devices include much hardware and complexity. They are designed for a dedicated purpose and they can not be used for various applications simultaneously, since, changing the hardware every-time is risky. Joseph Mittola proposed a new concept software defined radio (SDR) in which major hardware components can be implemented in software to reduce the hardware complexity, cost and to improve the reconfigurability [22]. In SDR, major signal processing can be done on general purpose processor (Computer or Mobile) and the processed signal is sent to hardware to do wireless transmission. Therefore, SDR provides more flexibility to apply for various applications just by changing the software. Chi-Hang Hsu et al., proposed a ubiquitous seamless mobile nursing cart (u-SMNC) with software defined radio for healthcare enterprises [23]. Currently, SDR is being used for military, commercial and hospital environments, Santiago et al., presented the applications of SDR technology in hospital environments [24]. Catarinucci et al., designed an IoT based smart architecture to monitor and patients contentiously within the hospital and its surroundings [25]. In my contribution, a novel architecture is designed using SDR technology for improving the communication among physicians and patients and also providing the authentication for patients.

II. SOFTWARE DEFINED RADIO

The software defined radio (SDR) testbed is shown in Figure 1 in which Universal Software Radio Peripheral (USRP) N210 [26] employed as hardware platform and GNU Radio [27] as software. As shown in Figure 1, the incoming radio frequency (RF) signal from a patient is converted in to intermediate frequency (IF) signal and then in to baseband signal at hospital using SDR platform. Incoming RF signal is processed through mixer to extract the original signal and then sent through analog to digital converter (ADC) to convert analog signal to digital signal (ADC) and decimated in to baseband signal by digital down converter (DDC). The baseband signal is now processed to the GNU Radio installed computer via Ethernet cable. Required baseband processing such as source encoding, channel encoding, modulation, digital filtering etc is performed. In the receiver path, all the reverse operations such as demodulation, channel decoding, source decoding, interpolation, digital to analog conversion (DAC) are performed and then sent in to the air [28].

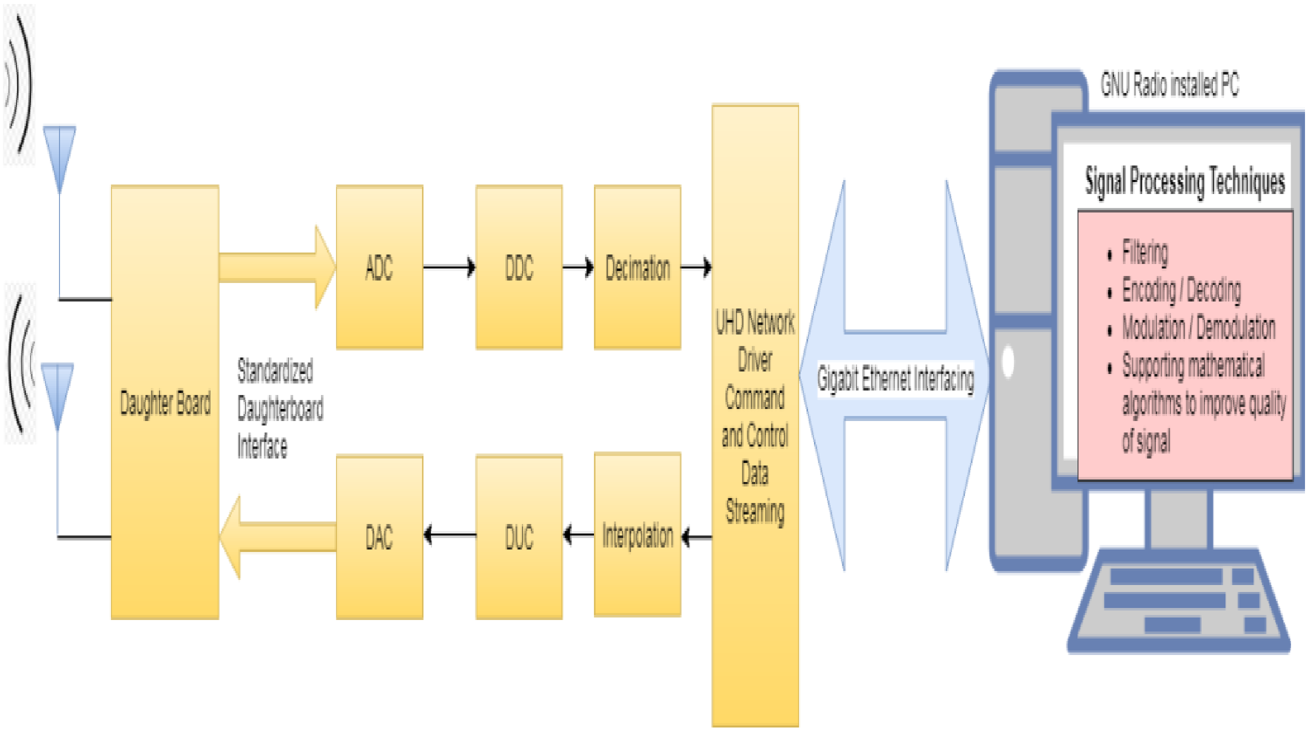

Fig. 1: Block diagram of Software Defined Radio.

III.PROPOSED SYSTEM MODEL

Software Defined Radio based smart architecture is proposed in this paper due to its intelligent and simple network architecture as shown in Figure 2. The proposed system mainly focuses on healthcare environments, in which three hospitals, nine patients, three client clouds and one server cloud are assumed. At each hospital one SDR platform is placed which acts as one access point. In each network, three patients are communicated at several distances from the hospital. Patients may use a different kind of handsets like 2G, 3G, and 4G, however, all these bands can be communicated by SDR which is the main advantage of SDR using in this system. Patient 1 (P1), P2 and P3 are communicating with hospital 1 at a distance of 3kms, 2kms and 5kms, respectively. P4, P5 and P6 are communicating with hospital 2 at a distance of 2.5kms, 3kms and 6kms, respectively. P7, P8 and P9 are communicating with hospital 3 at a distance of 3kms, 2kms and 5kms, respectively. SDR monitors and tracks the health condition of each patient in its coverage area, however, before communicating a patient it checks the authorization of that particular patient. An authorized RFID is given to each patient which is designed based on a separate coding and modulation method for each patient by the hospital authority. If predetermined modulation and coding is not matched, authorization will be failed and the communication between patient and hospital will be declined. In such case, patient needs to contact the hospital authority to continue his communication with SDR. If any illness is found in a patient, SDR unit will send the status information of health as a text message to the patient as well as a guardian. If any significant illness is found and the patient is not contacted the hospital, then hospital people will contact the patient and an ambulance will be sent to the patient location with necessary medication. In this way, my proposed system improve the healthcare infrastructure.If any patient is entering from one SDR network to another network,

his authentication will be tested automatically and he will be treated as a patient for the second SDR network. If one SDR network is busy with number of patients, some patients will be treated by other network and this action will be taken care by the central unit cognitive radio (CR). Generally, cognitive radio (CR) senses the environment and manages the available spectrum. If two patients will try to contact a single hospital, cognitive radio allocates appointment based on the seriousness of the patient. Each patient’s health information is stored in local client clouds and the significant information is also stored in server cloud by reducing the burden on server client.

IV. RESULTS AND DISCUSSION

In this section, three SDR platforms are placed at various distances and tested by changing distance among them as well as patients. The proposed system is analyzed by placing three SDR units, 9 patients’ user data at various places with several distances as shown in Figure 2. The experimental results are analyzed in terms of signal to noise ratio (SNR), bit error rate (BER) and throughput. The results are presented separately for hospital 1, hospital 2 and hospital 3 (SDRs) in Tables 1, 2 and 3, respectively. It can be observed from tables that, the patient who is near by the hospital has high SNR, low BER and high throughput, and the patient who is far away from the hospital has low SNR, high BER and low throughput. Therefore, it can be concluded that higher SNR patients can communicate easily with hospital. For improving the communication between hospital and patient, higher modulation techniques can also be used. Furthermore, experimental results of the proposed architecture is analyzed in terms of sample noise voltage, signal to noise ratio (SNR), bit error rate (BER) and throughput.

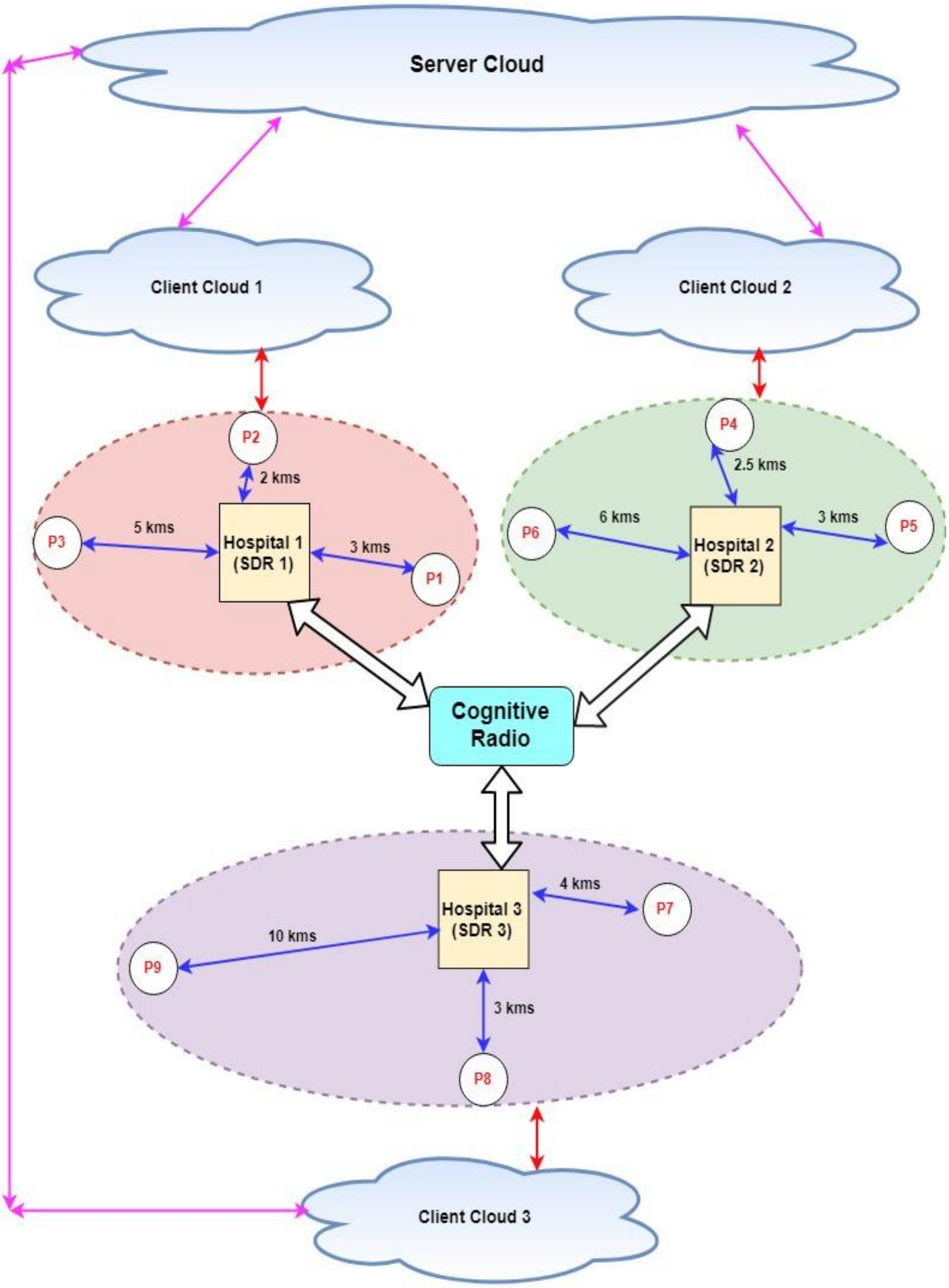

Fig. 2: Block diagram of Software Defined Radio.

Table 1: Experimental results obtained at Hospital 1 (SDR 1).

SNR (dB)			BER			Throughput (Mbits/sec)		
P1 (3 Kms)	P2 (2 Kms)	P3 (5 Kms)	P1 (3 Kms)	P2 (2 Kms)	P3 (5 Kms)	P1 (3 Kms)	P2 (2 Kms)	P3 (5 Kms)
24	30	20	10^{-6}	10^{-8}	10^{-4}	5	8	3

Table 2: Experimental results obtained at Hospital 2 (SDR 2).

SNR (dB)			BER			Throughput (Mbits/sec)		
P4 (2.5Kms)	P5 (3 Kms)	P6 (6 Kms)	P4 (2.5 Kms)	P5 (3 Kms)	P6 (6 Kms)	P4 (2.5 Kms)	P5 (3 Kms)	P6 (6 Kms)
28	24	18	10^{-7}	10^{-6}	10^{-3}	7	5	2.8

Table 3: Experimental results obtained at Hospital 3 (SDR 3).

SNR (dB)			BER			Throughput (Mbits/sec)		
P7 (4 Kms)	P8 (3 Kms)	P9 (10 Kms)	P7 (4 Kms)	P8 (3 Kms)	P6 (10 Kms)	P7 (4 Kms)	P9 (3 Kms)	P9 (10 Kms)
22	24	5	10^{-5}	10^{-6}	10^{-1}	4.5	5	1

V. CONCLUSION

This paper described the proposed smart architecture for healthcare applications based on software defined radio (SDR). A detailed review literature in the field of wireless communication for medical application is presented chronically and especially focused on SDR applications for healthcare. For the experimental purpose, three hospitals and 9 patients are assumed at several distances and corresponding results are tabulated. It is concluded from the obtained results that a patient who is near by the hospital has high SNR with high throughput and low BER can communicate successfully with the hospital than far user. Therefore, the implementation cost is reduced by employing SDR testbed. In future, I would like to extend the system in terms of number of hospitals, patients and also by placing patients at long distances by maintaining low BER, high SNR and high throughput.

REFERENCES

1. Meserow, Francis P, Wireless communication system, U.S. Patent No. 2,883,523. 1959.
2. D. A. Brody, J. C. Bradshaw and J. W. Evans, A “Theoretical Basis for Determining Heart-Lead Relationships of the Equivalent Cardiac Multipole”, *in IRE Transactions on Bio-Medical Electronics*, 8(2), 1961, pp. 139-143.
3. P. R. Gastonguay and C. V. Nelson, “Method for Measuring Dipole Parameters of Isolated Hearts and Muscles-Application to Frog Gastrocnemius”, *in IEEE Transactions on Biomedical Engineering*, 15(4), 1968, pp. 289-297.
4. R. S. Ledley, Analysis of Cells, *in IEEE Transactions on Computers*, 21(7), 1972, pp. 740-753.
5. J. Kohli, Medical imaging applications of emerging broadband networks, *in IEEE Communications Magazine*, 27(12), 1989, pp. 8-16.
6. K. Pahlavan, T. H. Probert and M. E. Chase, “Trends in local wireless networks”, *in IEEE Communications Magazine*, 33(3) (1995) 88-95.
7. N. J. Dowler and S. R. J. Holland, “The evolutionary design of an endoscopic telemanipulator”, in IEEE Robotics & Automation Magazine, 3(4) (1996) pp. 38-45.
8. C. E. Chronaki, D. G. Katehakis, X. C. Zabulis, M. Tsiknakis and S. C. Orphanoudakis, WebOnCOLL: “medical collaboration in regional healthcare networks”, *in IEEE Transactions on Information Technology in Biomedicine*, 1(4), (1997) pp. 257-269.
9. S. Pavlopoulos, E. Kyriacou, A. Berler, S. Dembeyiotis and D. Koutsouris, “A novel emergency telemedicine system based on wireless communication technology-AMBULANCE,” *in IEEE Transactions on Information Technology in Biomedicine*, 2(4), (1998) pp. 261-267.
10. G. Anogianakis, S. Maglavera and A. Pomportsis, “Relief for maritime medical emergencies through telematics,” *in IEEE Transactions on Information Technology in Biomedicine*, 2(4), (1998), pp. 254-260.
11. G. C. Giakos, “Emerging imaging sensor technologies from aerospace to healthcare”, *in IEEE Instrumentation & Measurement Magazine*, 1(4), (1998), pp. 16-19.
12. Xiaohui Liu, Gongxian Cheng and J. X. Wu, “AI for public health: self-screening for eye diseases”, *in IEEE Intelligent Systems and their Applications*, 13(5) (1998) 28-35.
13. K. Murakawa, M. Kobayashi, O. Nakamura and S. Kawata, “A wireless near-infrared energy system for medical implants”, *in IEEE Engineering in Medicine and Biology Magazine*, 18(6) (1999) 70-72.
14. R. Beuscart, J. M. Renard, D. Delerue and A. Souf, “Telecommunication in healthcare for a better coordination between hospitals and GP’s: routine application of the“ISARTelematics” *project*, *in IEEE Transactions on Information Technology in Biomedicine*, 3(2), (1999), pp. 101-108.
15. D. Feng, Information technology applications in biomedical functional imaging, *in IEEE Transactions on Information Technology in Biomedicine*, 3(3), (1999), pp. 221-230.
16. A. Kara, “Protecting privacy in remote-patient monitoring”, *in Computer*,34(5), (2001), pp. 24-27.
17. W. G. Scanlon and N. E. Evans, Numerical analysis of bodyworn UHF antenna systems, in Electronics & Communication Engineering Journal, 13(2), (2001), pp. 53-64.
18. P. Boilot et al., “Classification of bacteria responsible for ENT and eye infections using the Cyranose system,” *in IEEE Sensors Journal*, 2(3), (2002), pp. 247-253.
19. S. Arnon, D. Bhastekar, D. Kedar and A. Tauber, “A comparative study of wireless communication network configurations for medical applications,” *in IEEE Wireless Communications*, 10(1), (2003), pp. 56-61.
20. E. B. Sloane, Using a decision support system tool for healthcare technology assessments, in IEEE Engineering in Medicine and Biology Magazine, 23(3), (2004), pp. 42-55.
21. J. X. Wu, P. T. Huang, C. H. Lin and C. M. Li, “Blood leakage detection during dialysis therapy based on fog computing with array photocell sensors and heteroassociative memory model”, *in Healthcare Technology Letters*, 5(1), (2018), pp. 38-44.
22. J. Mitola, Software radios-survey, critical evaluation and future directions, *IEEE National Telesystems Conference*, 1992.
23. Chi-Hang Hsu et al., “Mobile nursing cart with software defined radio for healthcare enterprises”, *TENCON 2011 - 2011 IEEE Region 10 Conference*, Bali, 2011.
24. Chvez-Santiago, Raul, et al. “Applications of software-defined radio (SDR) technology in hospital environments, Engineering in Medicine and Biology Society (EMBC)”, *35th Annual International Conference of the IEEE*, 2013.

25. Catarinucci, L., De Donno, D., Mainetti, L., Palano, L., Patrono, L., Stefanizzi, M. L., & Tarricone, L, "An IoT-aware architecture for smart healthcare systems". *IEEE Internet of Things Journal*, 2(6), (2015), pp. 515-526.
26. MartinBraun, Ettus Research, Available at URL: https://www.ettus.com/product/details/UN210-KIT
27. Richard Stallman, Available at URL: www.gnuradio.org
28. Bathula Siva Kumar Reddy, "Experimental Validation of Timing, Frequency and Phase Correction of Received Signals Using Software Defined Radio Testbed." *Wireless Personal Communications*, 101, (4), (2018): 2085-2103.

AUTHORS PROFILE

B. Siva Kumar Reddy is an is an Associate Professor, Department of Electronics and Communication Engineering, KLEF, Guntur (dt), Andhra Pradesh, India. He has received B.Tech (Electronics and Communication Engineering) and M.Tech (Very Large Scale Integrated Circuits Design) degrees from Jawaharlal Nehru Technological University, Hyderabad (JNTUH), PhD in the field of Wireless Communications from National Institute of Technology, Warangal, India, in 2009, 2012 and 2016, respectively. His area of research includes Multi Carrier Modulations, OFDM, NOMA, internet of Things (IoT), PAPR Reduction techniques, Spectral leakages, Adaptive Modulation and Coding, Spectrum Sensing, Channel Estimation/ Equalization/ Synchronization, 3GPP, WiMAX, LTE, and Software Defined Radio. He is an ISTE (Indian Society for Technical Education) life time member and IDES (Institute of Doctors, Engineers and Scientists).

N.L. Pratap is an is an Assistant Professor, Department of Electronics and Communication Engineering, KLEF, Guntur (dt), Andhra Pradesh, India. His area of research includes computer networks, cognitive radio and computer architectures.