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Improving Energy Efficiency based Aware Link Adaptation for Multiple-Input Multiple-Output OFDM Wireless Networks

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Abstract—This paper presents the improving energy efficiency based aware link adaptation for multiple-input multiple-output (MIMO) Orthogonal frequency division multiplexing (OFDM) wireless networks. The practical link adaptation algorithm for MIMO-OFDM is presented. The proposed solution is based on sounding the channel periodically and choosing the optimal mode that will maximize the throughput or energy efficiency (EE) while satisfying the application's quality of service (QoS) requirements. The computational complexity of the algorithm and determination of sounding period by novel closed form solutions and iterative algorithms are easily determined. Realistic link level simulations confirm that the proposed solution achieves significant improvement over existing link adaptation algorithms when the aim is to maximize the throughput, and provides orders of magnitude gain in energy efficiency compared to poorly chosen fixed modes when used for energy efficiency maximization purposes.

Keywords—Link Adaptation; Multiple-Input Multiple-Output (MIMO); Orthogonal Frequency Division Multiplexing (OFDM); Energy Efficiency (EE); Wireless Networks;

I. INTRODUCTION

With the rapid and radical evolution of information and communication technology (ICT), corresponding energy consumption is also growing at a staggering rate. Furthermore, it has been reported that mobile operators are already among the top energy consumers, for example, Telecom Italia is the second largest energy consumer in Italy and energy consumption of mobile networks is growing much faster than ICT on the whole. Moreover, as the mass deployment of 3G systems in developing countries and later 4G systems worldwide occurs, mobile communications will consume significantly more energy if no effective actions are taken [1-8].

A large electricity bill results from the huge energy consumption of a wireless base station (BS). More than 50% of the total energy is consumed by the radio access part, where 50-80% is used for the power amplifier (PA) [9-16]. It is also pointed out that the energy bill accounts for approximately 18% of the Operation Expenditure (OpEx) in the mature European market and at least 32% in India. Therefore, from the operators' perspective, energy efficiency (EE) not only has great ecological benefits and represents social responsibility in fighting climate change, but also has significant economic benefits. Thus, it is urgent to shift from pursuing optimal capacity and spectral efficiency to efficient energy usage when designing wireless networks. From the users' perspective, energy-efficient wireless communication is also imperative.

According to the 2010 wireless smart-phone customer satisfaction and the iPhone received top marks in every category except for battery life [17-25]. The latest report in China also reflects the same problem. Based on the data in, up to 60% of the users complained that battery endurance was the greatest hurdle when using 3G services. Without a breakthrough in battery technology, the battery life of the terminal sets will be the biggest limitation for energy-hungry applications (e.g., video games, mobile P2P, interactive video, video monitors, streaming multimedia, mobile TV, 3D services, and video sharing) [26-38]. The Circuit energy and transmit energy trade-off for overall energy efficiency is shown in Fig 1.

II. SYSTEM MODEL

2.1. TDD multiuser MIMO system model

Consider the TDD MU-MIMO system shown in Fig. 2, where a BS is serving K users. The BS has M antennas and each user has one antenna. We consider zero-forcing (ZF) precoding at the BS because it is a practical low complexity linear precoding scheme and it performs optimal among all the linear precoders at high SNR.

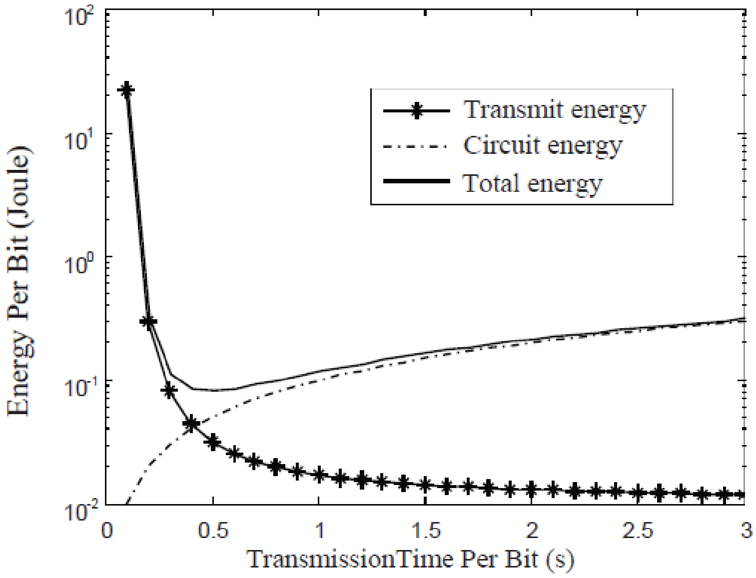

Fig. 1 Circuit energy and transmit energy trade-off for overall energy efficiency

Moreover, the SINR analysis under imperfect CSI at the transmitter is tractable when ZF precoder is employed. Due to these nice properties, ZF precoder has been frequently adopted in the system model of the papers on limited feedback.

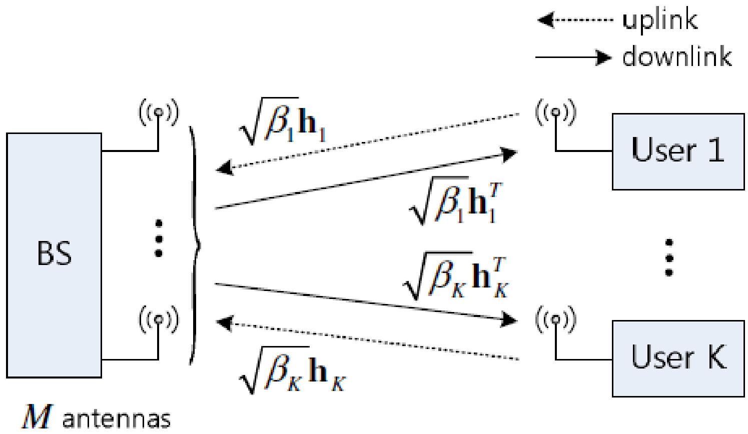

Fig. 2 TDD multiuser MIMO system model

Following typical assumptions in MU-MIMO research, we consider a narrowband system with flat fading channels. By assuming flat fading channel, the discussion on the tradeoff between the uplink pilot power and the downlink rate of users in a multiuser MIMO system can be simplified [39-56]. However, the discussion for narrowband channels can be extended to frequency-selective channels by employing orthogonal frequency division multiplexing (OFDM) because in OFDM systems the wideband channel is divided into many narrowband sub-bands, each experiencing flat fading. Assume ideal channel reciprocity and the uplink channels are the same as the downlink channels. In addition, assume block fading and the channel is constant in each frame [57-66].

2.2 Transmitter and receiver block diagrams for MIMO-OFDM system.

We consider a generic MIMO-OFDM system, depicted in Fig. 3, where the transmitter is equipped with *Nt* antennas, and the receiver uses *Nr* antennas. Information bits are first encoded with a convolutional encoder and punctured to achieve the desired code rate. The encoded bits are then parsed and interleaved over multiple spatial streams and subcarriers. The bits in each spatial stream are mapped to symbols by a quadrature-amplitude-modulator (QAM) which is followed by the spatial mapper. The spatial mapping (or antenna mapping) is a linear operation that transforms *Nss* (number of spatial streams) dimensional symbol vector into *Nt* dimensional signal, which is then transmitted after IFFT and cyclic prefix (CP) addition operations.

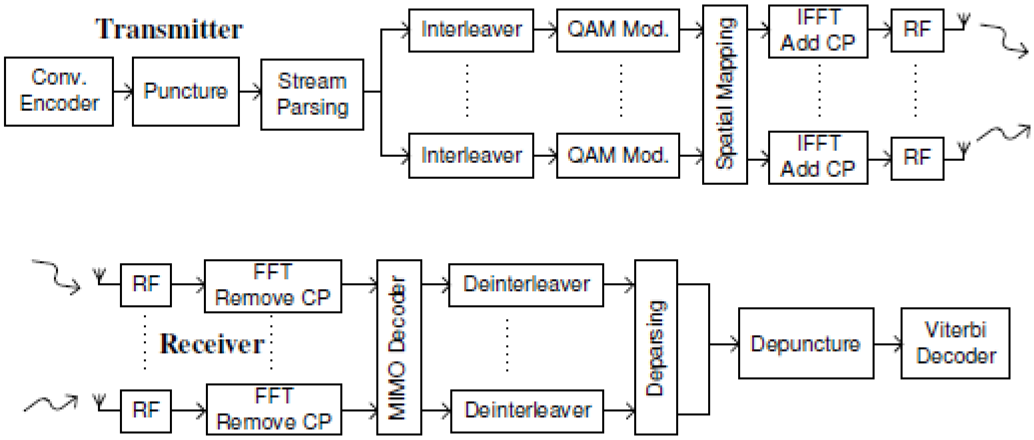

Fig. 3 Transmitter and receiver block diagrams for MIMO-OFDM system.

At the receiver, *Nr* dimensional time domain samples of the received signal are transformed back into the frequency domain by an FFT operation after removal of the CP. MIMO decoder is then used for separating individual spatial streams from the total received signal. Soft bits are then fed to the Viterbi decoder after the deinterleaving, deparsing and depuncturing operations. The system model is meant to be generic and applicable to most, if not all, MIMO-OFDM systems with minor modifications. Transmitted QAM symbols and precoding matrix are normalized so that the transmitted signal has a power of PT at each antenna. An $Nss \times Nr$ MIMO decoder matrix W is applied to the received signal to obtain the estimate of x, $\hat{x} = Wy$. The Minimum-Mean-Squared-Error (MMSE) decoder is the optimal solution to W among the class of linear decoders in the sense of minimizing the mean-squared error. At the output of the MMSE decoder, the PPSNR corresponding to the kth spatial stream for each subcarrier is calculated.

The PPSNR indicates the ratio of the power of the signal of interest to the power of the residual interference from other spatial streams plus the residual noise power. PPSNR has been used in the literature for error rate calculation and link adaptation purposes since the channel after the MMSE decoder can be treated as an additive white Gaussian noise (AWGN) channel which simplifies the error rate calculations. Information bits are first encoded with a convolutional encoder and punctured to achieve the desired code rate. The encoded bits are then parsed and interleaved over multiple spatial streams and subcarriers. The bits in each spatial stream are mapped to symbols by a quadrature-amplitude-modulator (QAM) which is followed by the spatial mapper.

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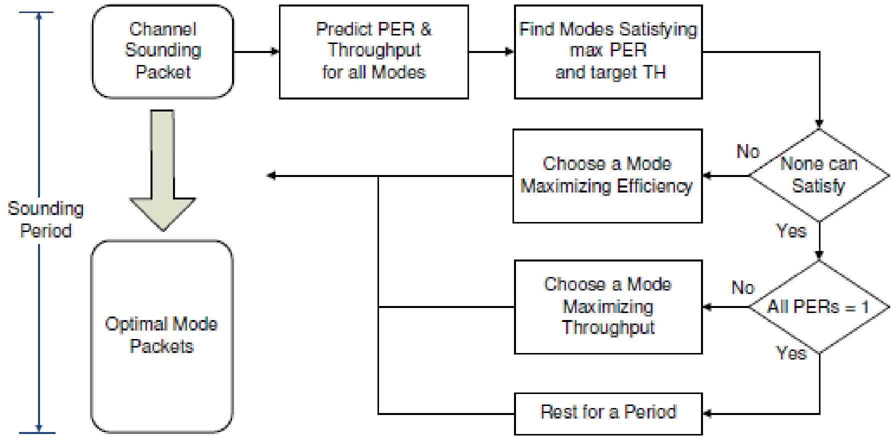
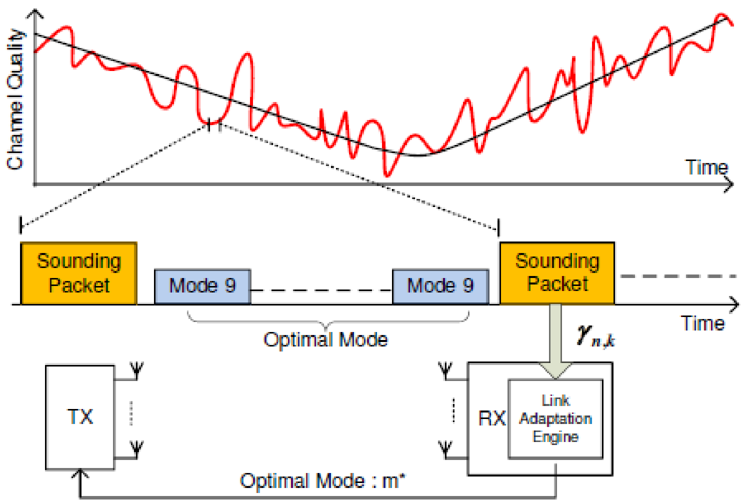
III. PROPOSED LINK ADAPTATION PROTOCOL

3.1. Link Adaptation Problem Definition

Past work dealing with the link adaptation problem has mostly focused on maximizing the link throughput subject to QoS constraints. The energy-aware fast link adaptation protocol is shown in Fig.4.



(a) Flowchart for the algorithm



(b) Overview of the link adaption process

Fig. 4 Energy-aware fast link adaptation protocol

The throughput maximization problem can be formally written as maximize *(1−PER) LT(bps)* subject to $PER \leq PERmax$ where *PERmax* is the maximum allowed instantaneous (or short term) packet error rate which is usually determined by the application, *L* is the packet length in number of information bits, and *T* denotes the total time needed to transmit the packet including the packet overheads and the time spent on the MAC layer related tasks. When our objective is to communicate

L bits across a channel, maximization of throughput will reduce the total transmission time, but it will not necessarily maximize the energy efficiency of the system. The objective of energy-aware link adaptation on the other hand, is to minimize the total energy consumed in the link per successfully received bit, which is equivalent to maximizing the number of successfully received bits normalized by the total energy consumption of the link.

3.1.1. Energy Consumption Model:

We employ a comprehensive energy consumption model, which comprises the energy consumed in the RF and baseband portions of both the transmitter and the receiver. For the RF and baseband energy consumption calculation, and which were obtained from already published link adaptation works or based on actual implementation data for specific blocks. The total energy consumption of the link is a function of *Nss;Nt;Nr; PT* , modulation and code rate; therefore the link adaptation algorithm tries to optimize these parameters simultaneously for maximizing energy efficiency. We revisit the energy consumption model here briefly for completeness. The total energy consumption in the link is calculated as

$$Et = ERF + EBASE + EMIMO \qquad (1)$$

where *EBASE* is the energy consumption of the baseband blocks of the transmitter (*tx*) and receiver *(rx)* excluding the MIMO detector energy consumption, and *EMIMO* is the MIMO detector energy consumption.

3.2. PER Prediction Model

Prediction of the instantaneous PER of the link is the most critical task in the link adaptation process since the optimum mode is chosen based on the predicted PER. Unlike the other works, which are based on simulations and curve fitting methods, we employ a PPSNR based model for the PER prediction. The residual interference plus noise at the output of the MMSE decoder can be approximated in [17], hence the uncoded BER of the k^{th} spatial stream at the nth subcarrier.

3.3. Proposed PPSNR Based Fast Link Adaptation Protocol

The wireless channel changes rapidly due to the mobility of the transmitter, the receiver and the surrounding objects. As a result, the channel exhibits small-scale fading (fast-fading) in addition to the path loss and shadowing effects (large-scale effects or slow-fading. The link adaptation work is aimed at finding the optimal mode based on the average error rate performance and as such, disregards the fast-fading in the channel. However, significant performance improvements can be achieved if the link adaptation algorithms are designed to take into account the instantaneous (or short term) channel conditions, rather than making a decision based on the long term average behavior of the channel. The latter approach is called fast link adaptation, which aims to provide improved performance by tracking and responding to the rapid variations in the channel. Our PPSNR based fast link adaptation protocol is based on sounding the full MIMO channel periodically and determining the optimal mode to transmit. A mode m is a 6-tuple (PT , Nss, Nt, Nr, Modulation, Code Rate) containing the parameters to be optimized, and the optimal mode is defined as the one which has the maximum energy efficiency or throughput depending on the desired objective.

IV. SIMULATION

4.1. Simulation Setup and Assumptions

For simulation purposes, we assumed an IEEE 802.11n like system from which we have taken the parameters for our simulations. We assumed uniform modulation and uniform power allocation over all subcarriers and spatial streams. When *Nt* > *Nss*, spatial expansion mode is evoked, and the spatial streams are mapped onto the transmit antennas in around robin fashion. For instance, in the case *of*

Nt = 3;Nss = 2, the first spatial stream will be duplicated to the third transmit antenna with a proper cyclic delay. This provides diversity in frequency domain, known as cyclic delay diversity.We employed the simplified path loss and log-normal shadowing models in order to model the channel's large-scale behavior. In addition to these large-scale effects, the signal is affected by fast fading due to the mobility in the channel. For fast fading, we used the Jakes' Doppler model. Each tx-rx antenna pair is assumed to experience independent fading. We simulated a file transfer application, which requires all the lost packets to be retransmitted until all of them are successfully received. A target time is defined for the transmission of the file. The link adaptation algorithm thus calculates the target throughput in real time based on the remaining file size and the remaining time. We simulated the transmission of a file of size 40 Mbytes with a target completion time of 50 seconds.

4.2. Simulation Results

We present the simulation results of a realistic link scenario, where the receiver node moves away from the transmitter and returns back at varying speeds. Throughput vs time (upper plot), and PER vs time (lower plot) is shown in Fig. 5.

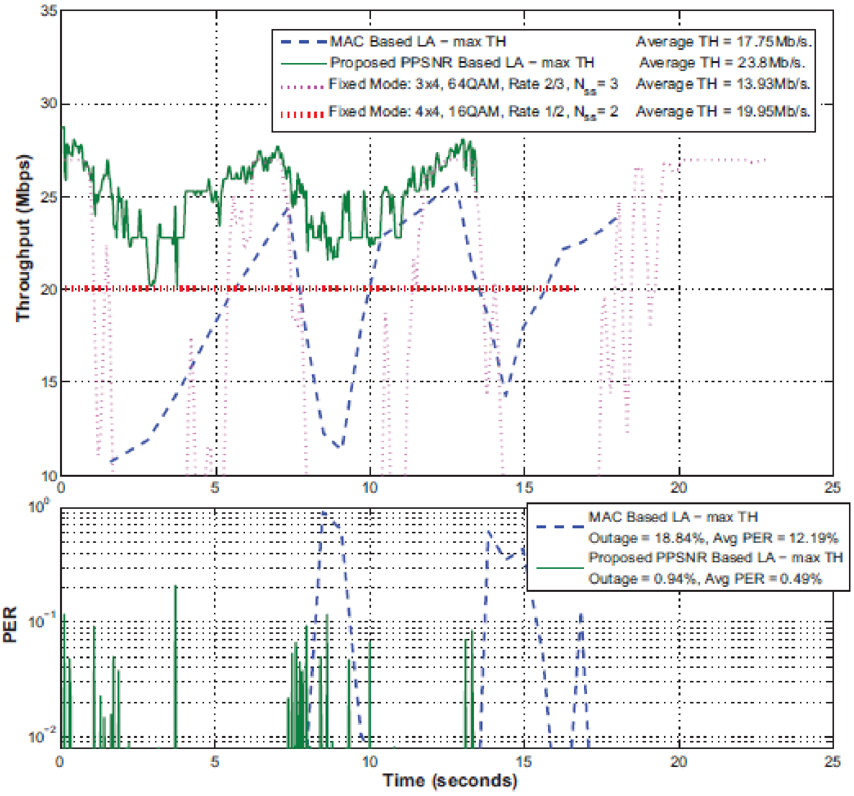


Fig. 5 Throughput vs time (upper plot), and PER vs time (lower plot)

It moves away from the transmitter for the first 3 seconds with a speed of 0.75 m/sec (6 Hz doppler), then it approaches the transmitter for 4 seconds with a speed of 0.50 m/sec (4 Hz doppler), then it moves away again for 2 seconds with a speed of 1 m/sec (8 Hz doppler), then returns back for 4 seconds with 0.50 m/sec speed. The MAC based protocol that we simulated is based on the Robust Rate Adaptation Algorithm (RRAA). This protocol measures the PER for several candidate modes (neighbor modes) within a short window of time, then switches to another mode if the achievable throughput at that mode is higher than the throughput at the current mode. The PERs and the achievable throughputs are measured by transmitting several packets for each mode in the candidate set. First, all the modes are ordered in terms of their rates. We define 6 neighbor modes to the currently used mode as our candidate set. 3 have lower rate than the current mode and 3 have higher rate, and all neighbor modes are probed along with the currently used mode. The Comparison of PSK

MIMO and Link Adaptation MIMO-OFDM with Doppler Effect is shown in Fig.6. The Performance of different schemes Versus the Normalized Doppler at SNR is shown in Fig.7.

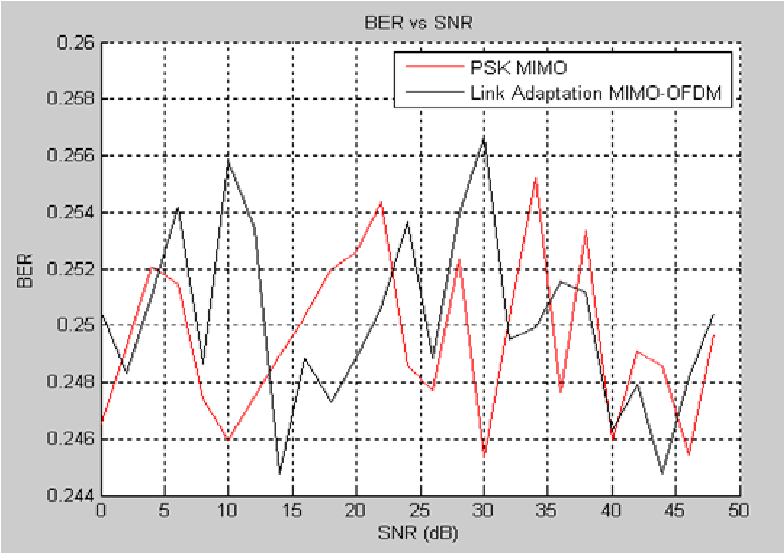


Fig.6. Camparsion of PSK MIMO and Link Adaptation MIMO-OFDM with Doppler Effect.

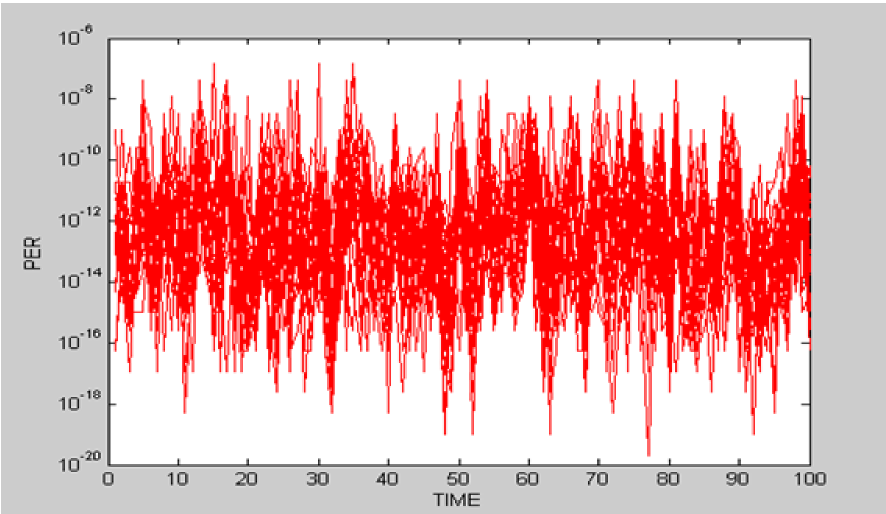


Fig.7. Performance of different schemes Versus the Normalized Doppler at SNR

The second simulated protocol is the proposed protocol with the objective of maximizing the throughput. The gains over these well performing fixed modes are 20% and 71%, respectively. This is because they always use the maximum transmit power, whereas the energy-aware protocol reduces the transmit power to save energy as long as the target QoS constraints are satisfied.

V. CONCLUSION

This PPSNR based link adaptation protocol for throughput or energy efficiency maximization in MIMO-OFDM communication links. The proposed algorithm tracks the channel changes fast enough so as to react to fast fading and chooses the optimal mode for the current state of the channel. The proposed solution employs a novel formulation of the PPSNR which does not require any matrix inversions, and greatly reduces the computational complexity. This new PPSNR formulation can be used in any other PPSNR based link adaptation methods. In addition, we present a smart transmit power ordering algorithm to eliminate redundant calculations to further reduce the complexity.

REFERENCES

I. B. Bougard et al., "SmartMIMO: an energy-aware adaptive MIMOOFDM radio link control for next-generation wireless local area networks," EURASIP J. Wireless Commun. and Netw., article ID. 98186, 2007.

II. M.ValanRajkumar, P.S.Manoharan, Modeling and Simulation of Three-phase DCMLI using SVPWM for Photovoltaic System, Springer Lecture Notes in Electrical Engineering, under the volume titled "Power Electronics & Renewable Energy Systems", Volume 326, Chapter No 5, January 2015, Pages 39-45.

III. M.ValanRajkumar, P.S.Manoharan, Harmonic Reduction of Fuzzy PI Controller based Three-Phase Seven-level DCMLI with SVPWM for Grid Connected Photovoltaic System, Journal International Review on Modeling and Simulations, Volume 6, No 3, June 2013, Pages 684-692.

IV. G. Miao, N. Himayat, and G. Y. Li, "Energy-efficient link adaptation in frequency-selective channels," IEEE Trans. Commun., vol. 58, no. 2, pp. 545–554, 2010.

V. A.Ravi, P.S.Manoharan, M.ValanRajkumar, "Harmonic Reduction of Three-Phase Multilevel Inverter for Grid connected Photovoltaic System using Closed Loop Switching Control", Journal-IREMOS, Volume 5, No 5, October 2012, Pages 1934-1942. ISSN: 1974-9821 (Print), 1974-982X (Online)

VI. P.Thirumurugan, P.S.Manoharan, M.ValanRajkumar, "VLSI Based Inverter Switching Control" in the proceedings of International Conference on Mathematical Modeling and Applied Soft Computing MMASC'12 – Coimbatore Institute of Technology on July 2012, Vol-2 (Page):965-973.

VII. S. Catreux, V. Erceg, D. Gesbert, and R.W. Heath, "Adaptive modulation and MIMO for broadband wireless data networks," IEEE Commun. Mag., vol. 40, no. 6, pp. 108–115, June 2002.

VIII. C.Hemalatha, M.Valan Rajkumar, G.Vidhya Krishnan, "Simulation and Analysis for MPPT Control with Modified firefly algorithm for photovoltaic system", International Journal of Innovative Studies in Sciences and Engineering Technology, Volume 2, No 11, Nov.2016, Pages 48-52.

IX. G.Vidhya Krishnan, M.Valan Rajkumar, C.Hemalatha, "Modeling and Simulation of 13-level Cascaded Hybrid Multilevel Inverter with less number of Switches", International Journal of Innovative Studies in Sciences and Engineering Technology, Volume 2, No 11, Nov.2016, Pages 43-47.

X. M.ValanRajkumar, P.S.Manoharan, FPGA Based Multilevel Cascaded Inverters with SVPWM Algorithm for Photovoltaic system, Elsevier Journal Solar Energy, Volume 87, Issue 1, January 2013, Pages 229-245.

XI. M.ValanRajkumar, P.S.Manoharan, Space Vector Pulse Width Modulation of Three-Phase DCMLI with Neuro-Fuzzy MPPT for Photovoltaic System, World Journal of Modelling and Simulation, Volume 10, No 3, August 2014, Pages 193-205.

XII. S. Cui, A. J. Goldsmith, and A. Bahai, "Energy-constrained modulation optimization," IEEE Trans. Wireless Commun., vol. 4, no. 5, 2005.

XIII. M.Valan Rajkumar, Prakasam, P. and Manoharan, P.S. (2016) Investigational Validation of PV Based DCDMLI Using Simplified SVM Algorithm Utilizing FPGA Tied with Independent Sources. Circuits and Systems, Volume 7, No 11, 3831-3848. http://dx.doi.org/10.4236/cs.2016.711320

XIV. H. V. Poor and S. Verdu, "Probability of error in MMSE multiuser detection," IEEE Trans. Inf. Theory, vol. 43, no. 3, pp. 858–871, 1997.

XV. P.Thirumurugan, P.S.Manoharan, M.ValanRajkumar, VLSI Based Space Vector Pulse Width Modulation Switching Control in the proceedings of IEEE International Conference on Advanced Communication Control and Computing Technologies ICACCCT 2012 on August 2012, ISBN No. 978-1-4673-2045-0 (Print) (Page):366-370.

XVI. M.ValanRajkumar, P.S.Manoharan, "Modeling, Simulation and Harmonic Reduction of Three-Phase Multilevel Cascaded Inverters with SVPWM for Photovoltaic System", Journal International Review on Modeling and Simulations, Volume 6, No. 2, April 2013, Pages 342-350. ISSN: 1974-9821 (Print), 1974-982X (Online)

XVII. M. Lacage, M. H. Manshaei, and T. Turletti, "IEEE 802.11 rate adaptation: a practical approach," in Proc. 2004 ACM MSWIN pp. 126–134.

XVIII. M.Valan Rajkumar, G.Ranjhitha, M.Pradeep, Mohammad Fasil PK, R.Sathishkumar, "Fuzzy based Speed Control of Brushless DC Motor fed Electric Vehicle", International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), Volume: 3, Issue: 3, March 2017, Pages 12-17. ISSN: 2455-4863 (Online).

XIX. M.Valan Rajkumar, J.Chandramohan, D.Aravind, M.Basker, "Performances Analysis of Power Factor Correction for PWM Control based Bridgeless Cuk Rectifier with Positive Output Voltage", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 116-121. ISSN: 2454-6410 (Online).

XX. S. Cui et al., "Energy-efficiency of MIMO and cooperative MIMO techniques in sensor networks," IEEE J. Sel. Areas Commun., vol. 22, no. 6, pp. 1089–1098, Aug. 2004.

XXI. K.Aswini, K.Nandhini, SR.Nandhini, G.Akalya, B.Rajeshkumar, M.Valan Rajkumar, "Simulation and Analysis of ASCAD Multilevel Inverter with SPWM for Photovoltaic System", International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), Volume: 3, Issue: 4, April 2017, Pages 1-9. ISSN: 2455-4863 (Online).

XXII. M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, "Modelling and Analysis of DC-DC Converter with Various MPPT Algorithms for PV System", International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET), Volume: 3, Issue: 4, April 2017, Pages 17-22. ISSN: 2455-4863 (Online).

XXIII. Y. R. Zheng and C. Xiao, "Improved models for the generation of multiple uncorrelated Rayleigh fading waveforms," IEEE Commun. Lett., vol. 6, pp. 256–258, June 2002.

XXIV. M.Valan Rajkumar, T.Indumathi, “Analysis of Low Power Multi-core Embedded Management for Energy Harvesting”, IOSR-Journal of Electrical and Electronics Engineering, Volume 12, Issue 2, Ver. II, March-April 2017, Pages 25-33. ISSN: 2320-3331 (Print) 2278-1676 (Online).

XXV. A.Ravi, M.Valan Rajkumar, P.S.Manoharan, “Harmonic Reduction of Three-Phase Eleven-level DCMLI with Fuzzy MPPT for Grid Connected Photovoltaic System”, International Journal of Applied Engineering Research (IJAER), Volume 10, No 2, 2015, Pages 3251-3268. ISSN: 0973-4562 (Print).

XXVI. O. A. Nasr, O. Y. Takeshita, W. Zhu, and B. Daneshrad, “Field trial results of a 4x4 MIMO-OFDM real time testbed,” in Proc. 2010 IEEEICC, pp. 1–5.

XXVII. M.Valan Rajkumar, J.Karthikeyan, P.S.Manoharan, “Modeling and Simulation of Multiphase DCMLI with SVPWM for Photovoltaic System”, International Journal of Applied Engineering Research (IJAER), Special Issue: Volume 9, No 24, 2014, Pages 8477-8483. ISSN: 0973-4562 (Print).

XXVIII. J. Chen, W. Zhu, B. Daneshrad, J. Bhatia, H. S. Kim, K. Mohammed, S. Sasi, and A. Shah, “A real time 4x4 MIMO-OFDM SDR for wireless networking research,” in Proc. 2007 EUSIPCO, pp. 1151–1155.

XXIX. M.ValanRajkumar, P.S.Manoharan, “Modeling and Simulation of Five-level Five-phase Voltage Source Inverter for Photovoltaic Systems”, Journal PrzegladElektrotechniczny, Volume 10, No. 10, October 2013, Pages 237-241. ISSN: 0033-2097 (Print)

XXX. H. S. Kim and B. Daneshrad, “Energy-constrained link adaptation for MIMO OFDM wireless communication systems,” IEEE Trans. Wireless Commun., vol. 9, no. 9, pp. 2820–2832, Sept. 2010.

XXXI. M.Valan Rajkumar, P.S.Manoharan, A.Ravi, “Simulation and an Experimental Investigation of SVPWM Technique on a Multilevel Voltage Source Inverter for Photovoltaic Systems”, Elsevier International Journal of Electrical Power and Energy Systems, Volume 52, Issue 9, November 2013, Pages 116-131. ISSN: 0142-0615 (Print), 1879-3517 (Online)

XXXII. SR.Nandhini, G.Akalya, K.Aswini, K.Nandhini, M.Valan Rajkumar, B.Rajeshkumar, “A New Topology of H-bridge based Multilevel Inverter for PV System with Reduced Switches”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 60-68. ISSN: 2454-6410 (Online).

XXXIII. M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, “A New DC-DC Converter Topology with Grey Wolf MPPT Algorithm for Photovoltaic System”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 54-59. ISSN: 2454-6410 (Online).

XXXIV. N.Kaliammal, J.Geetha, “Ternary logic circuit design using CNTFET”, International journal of Applied Engineering Research, Volume 10, No 5, pp 4699-4703, Feb 2015

XXXV. N.Kaliammal, Yogesh Chaba, “Performance Analysis of routing protocols in vehicular Adhoc networks for TCP applications”, International journal of Applied Engineering Research Volume 10, No 5,pp 4694-4698, Feb 2015

XXXVI. L.Malliga, K.Bommannaraja, M.Valan Rajkumar, “Investigation of FCM based Image Retrievel-Segmentation on Human Computational Intelligent Systems”, International Journal of Applied Engineering Research (IJAER), Special Issue: Volume 10, No 12, 2015, Pages 10769-10774. ISSN: 0973-4562 (Print).

XXXVII. T. Jensen et al., “Fast link adaptation for MIMO-OFDM,” IEEE Trans. Veh. Technol., vol. 59, no. 8, pp. 3766–3778, 2010.

XXXVIII. U.Suresh Kumar, P.S.Manoharan, M.Valan Rajkumar, “Feasibility Sensitivity Analysis in Potential Area for Standalone Hybrid Renewable Energy in Tamil Nadu, India”, Applied Mechanics and Materials Journal, under the volume titled “Advancements in Automation and Control Technologies", Volume 573, June 2014, Pages 757-766. ISSN: 1660-9336 (Print), ISBN-13: 978-3-03835-124-5 (Online).

XXXIX. C.Hemalatha, M.Valan Rajkumar, M.Gayathri, “IOT Based Building Monitoring System Using GSM Technique”, IOSR-Journal of Electronics and Communication Engineering (IOSR-JECE), Volume 12, Issue 2, Ver. III, March-April 2017, Pages 68-75. ISSN: 2278-8735 (Print) 2278-2834 (Online).

XL. S.Rashini, P.S.Manoharan, M.Valan Rajkumar, “Interfacing PV system to the Utility Grid using a Voltage Source Inverter”, Journal of Emerging Technologies Electrical Engineering, Special Issue- ICBDM 2013, Volume 1, No 1, March 2013, Pages 124-129. ISSN: 0973-2993 (Print)

XLI. S.Sathyaraj, M.Valan Rajkumar, J.Chandramohan, “Modeling and Simulation of Asymmetric Cascaded Multilevel Inverter with Reduced Switches using Multicarrier PWM Control”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), Volume 5, Issue 10, October 2016, Pages 8064-8071. ISSN: 2320-3765 (Print), 2278-8875 (Online)

XLII. G.Ranjhitha, M.Valan Rajkumar, “Implementation of Genetic Algorithm based Maximum Power Point Tracking for Photovoltaic System”, International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume 5, Issue 11, November 2016, Pages 18860-18868. ISSN: 2347-6710 (Print), 2319-8753 (Online)

XLIII. S.Sathishkumar, M.Valan Rajkumar, R.Yuvaraj, “Modeling and Analysis of Soft-Switched Interleaved Boost Converter for Photovoltaic System”, International Journal for Science and Advance Research in Technology (IJSART), Volume 2, Issue 11, November 2016, Pages 43-48. ISSN: 2395-1052 (Online)

XLIV. T. M. Schmidl and D. C. Cox, “Robust frequency and timing synchronization for OFDM,” IEEE Trans. Commun., vol. 45, no. 12, pp. 1613– 1621, Dec. 1997.

XLV. E. Eraslan, B. Daneshrad, and C.Y. Lou, “Performance indicator for MIMO MMSE receivers in the presence of channel estimation error,” IEEE Wireless Commun. Lett., vol. 2, no. 2, pp. 211–214, Apr. 2013.

XLVI. M.Sundaraperumal, M.Valan Rajkumar, A.Venkatesh, “Modeling and Analysis of Current Source Multilevel Inverter using PI Controllers with Multicarrier PWM Technique”, International Journal for Science and Advance Research in Technology (IJSART), Volume 2, Issue 11, November 2016, Pages 275-280. ISSN: 2395-1052 (Online)

XLVII. R.Yuvaraj, S.Sathishkumar, M.Valan Rajkumar, “Analysis of PV based Soft Switching Boost DC-DC Converter with Zero Current Switching Technique”, International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE), Volume 2, Issue 12, December 2016 Pages 1-5. ISSN: 2454-9762 (Print) 2454-9762 (Online)

XLVIII. M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, "A New MPPT design using Grey Wolf Optimization Techniques with DC-DC Converter for PV System", International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 3, March 2017, Pages 829-835. ISSN: 2395-1052 (Online)

XLIX. K.Nandhini, SR.Nandhini, G.Akalya, K.Aswini, M.Valan Rajkumar, B.Rajeshkumar, "Implementation of 21-level Asymmetrical Cascaded Multilevel Inverter with Reducing Number of Switches", International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 3, March 2017, Pages 809-818. ISSN: 2395-1052 (Online)

L. N.Kaliammal, G.Gurusamy, "Performance analysis of multicast routing and wavelength assignment protocol with dynamic traffic grooming in WDM Networks" International Journal of Communication System Volume 26, Issue 2, pp 198-211, Feb 2013

LI. N.Kaliammal,G.Gurusamy, "Multicast Routing and Wavelength Assignment for Capacity Improvement in Wavelength Division Multiplexing Networks", International Journal of Computer Science and Information Security, Volume 8, No. 7, pp 175-182. Oct 2010

LII. C. Isheden and G. Fettweis, "Energy-efficient link adaptation with transmitter CSI," in Proc. 2011 IEEE WCNC, pp. 1381–1386.

LIII. S.Sathishkumar, M.Valan Rajkumar, S.Vinothkumar, M.Maruthamuthu, A.Sounder, A.Kumaresan, "A New Design for DC-DC Converter Topology with MISO for Renewable Energy Resources", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 4, April 2017, Pages 143-149. ISSN: 2454-6410 (Online)

LIV. M.Valan Rajkumar, M.Mahakumar, M.Manojkumar, M.Hemaraj, E.Kumaravel, "Implementation of Various MPPT Algorithms with SEPIC Converter for PV System", International Journal of Engineering Research & Technology-Special Issue 2017, Volume 5, Issue 13, 2017, Pages 589-593. ISSN: 2278-0181 (Print)

LV. G.Akalya, K.Aswini, K.Nandhini, SR.Nandhini, M.Valan Rajkumar, B.Rajeshkumar, "Modelling and Analysis of Multilevel Inverter for Photovoltaic System", International Journal of Advanced Research Methodology in Engineering & Technology (IJARMET), Volume 1, Issue 3, May 2017, Pages 36-43. ISSN: 2456-6446 (Online)

LVI. Mohammad Fasail PK, M.Pradeep, R.Sathishkumar, G.Ranjhitha, M.Valan Rajkumar, "Speed Control BLDC Motor using Fuzzy Logic and PID Controller fed Electric Vehicle", South Asian Journal of Engineering and Technology, Volume 3, Issue 3, March 2017, Pages 118-131. ISSN: 2454-9614 (Print)

LVII. G. Miao, N. Himayat, G. Y. Li, and S. Talwar, "Low complexity energyefficient scheduling for uplink OFDMA," IEEE Trans. Commun., vol. 60, no. 1, pp. 112–120, Jan. 2012.

LVIII. H. V. Poor and S. Verdu, "Probability of error in MMSE multiuser detection," IEEE Trans. Inf. Theory, vol. 43, no. 3, pp. 858–871, 1997.

LIX. G.Vidhya Krishnan, M.Valan Rajkumar, D.Umakirthika, "Role of Internet of Things in Smart Passenger Cars", International Journal of Engineering And Computer Science (IJECS), Volume: 6, Issue: 5, May 2017, Pages 21410-21417. ISSN: 2319-7242 (Online).

LX. M.Valan Rajkumar, T.Indumathi, "Performance Analysis of PV based Low Power Multi-Core Embedded Management using Wireless Communication System", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 5, May 2017, Pages 129-136. ISSN: 2454-6410 (Online).

LXI. C.Hemalatha, M.Valan Rajkumar, M.Gayathri, "Performance Analysis of IoT based Secured Smart Building Monitoring System Interface using GSM Technique", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 5, May 2017, Pages 141-147. ISSN: 2454-6410 (Online).

LXII. P.Pushparani, M.Valan Rajkumar, R.Suganya, "Simulation and Analysis of SVHM Technique for DCMLI under Transient Conditions with Non-Linear Loads", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 11, November 2017, Pages 90-96. ISSN: 2454-6410 (Online).

LXIII. R.Suganya, M.Valan Rajkumar, P.Pushparani, "Simulation and Analysis of Boost Converter with MPPT for PV System using Chaos PSO Algorithm", International Journal of Emerging Technologies in Engineering Research (IJETER), Volume: 5, Issue: 11, November 2017, Pages 97-105. ISSN: 2454-6410 (Online).

LXIV. P.Pushparani, M.Valan Rajkumar, R.Suganya, "Modeling and Analysis of Maximum Power Point Tracking for Photovoltaic System using Fuzzy Logic Controller", International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 11, November 2017, Pages 298-306. ISSN: 2395-1052 (Online)

LXV. R.Suganya, M.Valan Rajkumar, P.Pushparani, "Modeling and Analysis of Sinusoidal PWM Technique for CHB Multilevel Inverter for Photovoltaic System", International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 11, November 2017, Pages 307-315. ISSN: 2395-1052 (Online)

LXVI. M.Sundaraperumal, M.Valan Rajkumar, D.Aravind, "Simulation and Analysis of APOD Pulse Width Modulation Technique for Z-Source Cascaded Multilevel Inverter for Photovoltaic System", International Journal for Science and Advance Research in Technology (IJSART), Volume 3, Issue 11, November 2017, Pages 816-824. ISSN: 2395-1052 (Online)