www.idosr.org
©IDOSR PUBLICATIONS
International Digital Organization for Scientific Research
IDOSR JOURNAL OF APPLIED SCIENCES 6(1): 137-152, 2021.

ISSN: 2550-793

SIMULINK Investigation of the Performance Evaluation of HIPERLAN/2 using Different Coding, Decoding and Error Correcting Techniques

Yoni Humphrey Maina and Ndala Mukanda
Department of Electrical, Electronic and Computer Engineering Technology, Adamawa State Polytechnic, Yola, Nigeria.
Email:yonicalgery@yahoo.com

ABSTRACT

HIPERLAN/2 (High performance radio local area network) is a wireless standard established by the ETSI (European telecommunications standard institute). It uses the OFDM (Orthogonal Frequency Division Multiplexing) which operates in the 5 GHz frequency band with a bit rate of up to 54 Mbps. In this work we studied the principles of operation of wireless digital communications with respect to convolution encoding and Subcarrier interleaving. We then evaluated critically the performance of a system models in MATLAB/ Simulink modelling then applying convolutional codes for encoding and Viterbi decoder for decoding while we obtained the corresponding BERs. From model A and B, we found out that the coded system out performs a non-coded system because of addition of redundancy. We also compared models B and C, which shows an insignificant difference in the Bit Error Rate (BER) performance improvement while applying interleaving to a system with no burst noise. In model E the presence of burst noise while applying interleaving showed an improvement in the performance of BER. In model F we implemented one different convolution encoder (poly2trellis) of the same constraint length along with its associated trellis decoding which showed identical polynomials will exhibit the worst performance, while there are other combinations such as the standard [171 133] will have good performance at low SNR. Among those there are those polynomials which will have poor performance at low SNR but improve with better SNR. We have also observed that the polynomials must also be well considered as they can affect the system catastrophically in the case where they are identical. Overall we have shown; a thorough understanding of the principal of wireless digital communication, we have critically evaluated the performance of appropriate digital communication system components, and have demonstrated our ability to design alternative system components.

Keywords: Simulation, HiperLAN/2, OFDM, BER, SNR.

INTRODUCTION

The demand for higher data rate has been on the increase mildly because of the recent increase in demand higher data rate applications for mobile by consumers which has driven the growth of new technologies. One of those major technologies standards that have been defined is the HIPERLAN/2 (High performance radio local area network). It was intended to provide a high speed integrated services for data, voice and video. This technology is well suited to complement 3g cellular networks, and stems its origin in HIPERLAN/1 which mainly supports asynchronous data transfer and, for this purpose applies carrier sense multiple access CSMA with Collision avoidance [1]. The one drawback for this technology is that it was not able to deliver a guaranteed QoS and utilized a BE transportation route, as such it was imperative to define a standard that could deliver time critical service – this was one of the motivations for defining a new standard in the form of HIPERLAN/2.

In order to improve the BER of the channel it is common practice to utilize forward error correcting techniques (FEC), among them block codes and convolution codes have been of particular importance. For this report we pay particular importance to convolution codes, convolution encoder and the Viterbi decoder – they form a powerful error correcting with a wide range of application. It is also common practice to couple FEC with interleaving, whereby the Sub Carriers (SCs) assigned to various users are shuffled and mixed up. The polynomials which form the generator function of the convolution encoder are of utmost important, in particular we will show how different polynomials impact the system in different ways in terms of performance, we also see how identical polynomials in particular impact the system. The rest of the report is divided as follows:

HIPERLAN/2 is reliant on ad-hoc networking combined with a cellular networking topology, supporting two basic modes of operation: centralized and direct. In the centralized topology is used for cellular deployment where each radio cell is controlled by an AP covering a certain geographical area, in contrast the direct topology deployed in ADHOC is used typically where the serving cell covers the whole area i.e. in a home [1].

HIPERLAN/2 uses a reservation based TDMA for MAC interface, prompting different error control mechanisms: The acknowledgement mode – ARQ, The repetition mode and the unacknowledged mode. To cope with the varying link quality, a link adaptation mechanism is used, whereby a series of measurements is done periodically to determine the link quality – the modulation scheme and code rate are then adjusted accordingly [1]. QoS is supported by allowing different bearers (BERs) to be set up and treated differently at the AP – which decides on the appropriate error control mechanism to utilize, it also then determines which BERs to permit access to the radio and sets limitations on the amount of data they can transmit [1].

THE PHYSICAL LAYER

The physical layer is also responsible for providing several physical layers with different modulation schemes supported by HLAN2 (BPSK, QAM, QPSK) in order to support link adaption like previously stipulated.

OFDM has been selected as the modulation scheme for HIPERLAN/2 due to its resistance to multipath and fading, it also shows high performance on highly dispersive channels [2]. This is a frequency division multiplexing technique whereby frequency bands may overlap, in order to utilize the bandwidth more efficiently provided these overlapping bands or subcarriers (SCs) are orthogonal to each other [3]. In order to exploit such SCs, an FFT operation is performed on the user data, the inverse operation will is performed at the receiver to recover the signal. In order to combat the Inter Symbol interference that will result as a consequence of overlapping the symbols, OFDM incorporates the cyclic prefix, which is a circular extension of the symbol period [3]. Fig.1 below illustrates the system block diagram that details the key features described in this section. One drawback of OFDM is the power amplifier back-off; OFDM requires 2-3 dB higher back-off than single carrier modulation [1].

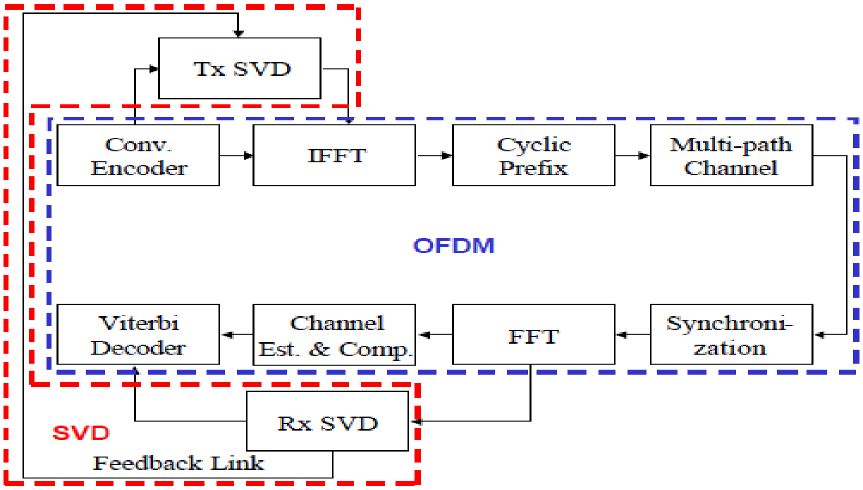


FIGURE 1: OFDM SYSTEM DIAGRAM[1]

RELATED WORKS

In [6] the authors present the simulation of convolutional encoder using MATLAB. The performance and analysis was done by changing the rates of convolutional encoder and error of binary symmetric channel. When the SNR was fixed and changing the date rate, it was found that; rate 2/3 gives better results than 1/2 and 1/3. When keeping the code rate at 1/2 and altering SNR it shows that with the minimum SNR it gives better results.

The authors in [8] study various decoding algorithms using MATLAB software – Viterbi Decoding, Log-MAP and SOVA Turbo Codes. They also set up an image transfer application to comparatively evaluate their performance. The chosen performance metrics were BER and the calculation of complexity; they generated traffic transmitting it over an AWGN channel with BPSK modulation. They form 50 information block, each 100 bits long with a 1/2 code ratio while increasing SNR from 0 to 4.

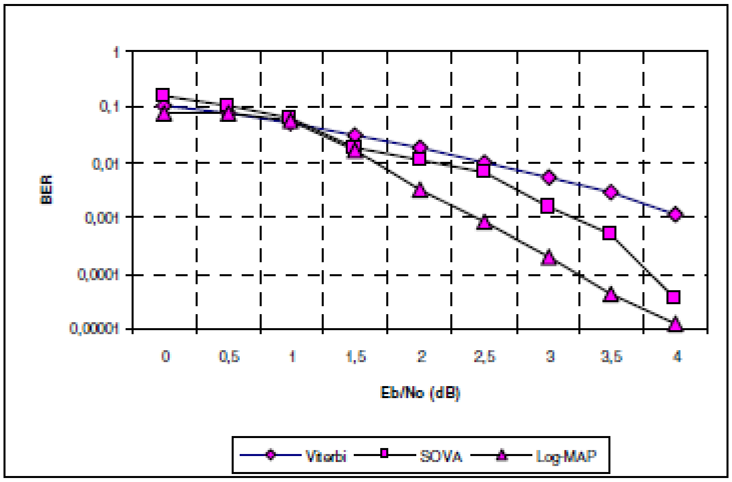


FIGURE 1: BER PEFROMANCE

It was found that at the best performance Turbo codes showed almost 100 times better BER performance, while more sophisticated complexity is assigned to turbo codes with the numerous iterations required to produced optimal results. When 5 iterations were considered, they found that Log-Map decoding algorithm has 20 times and SOVA has 2 times more complexity than Viterbi.

It is quite clear from those studies and many more [4, 5, 7, 8] that Turbo codes are the leading candidate despite their complexity, however for the course of this report we lay particular focus to the Viterbi Decoding system. On comparing this system to other FEC techniques we found that it holds distinct advantage. The authors of [4] cover various topics in the digital communications field – they derive fig.6 below which compares Viterbi to other FEC Codes. It is evidently clear that Viterbi out performs popular codes such as; Hamming codes, Read Solomon (RS), Block and Golay.

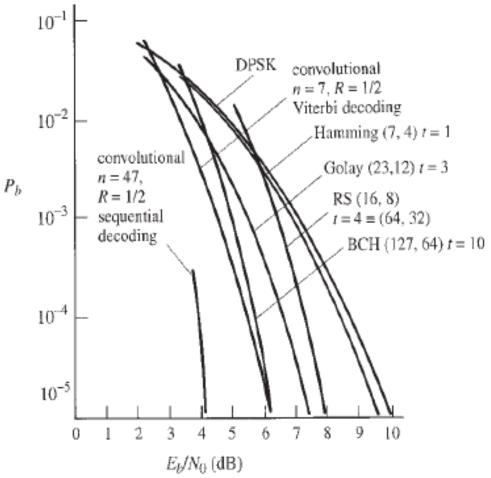


FIGURE 2: VITERBO PEFROMANCE

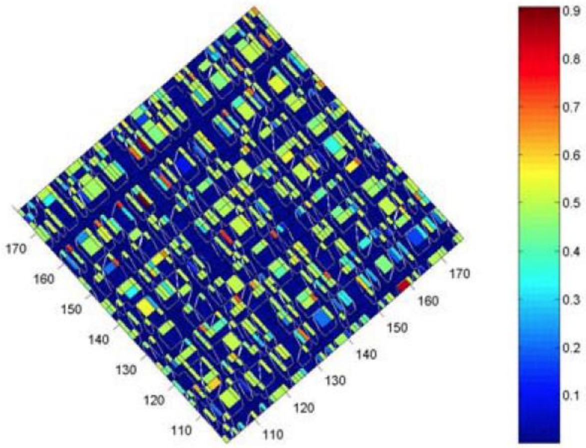


FIGURE 3: TOP VIEW OF BER PEFROMANCE

In order to simplify Viterbi decoding for high rate codes, the authors in [9] consider employing puncturing – which is obtained by periodically deleting a part of the bits of low-rate convolutional code. The authors derive a graph where they compare for the same BER the coding gain. The coding gain can be defined as the difference of the required SNR in the un-coded and coded systems for obtaining the specific BER under the same information bit rate [9]. In that paper they compared all codes at BER 10^{-6}, and they found that for the same rate punctured codes, the coding gain increases by 0.2 – 0.5 dB according to the increase of the constraint length v by 1. In summary, they conclude that punctured codes are useful for realizing the Viterbi decoder for high data rates. It is worth noting that in order to nullify the BER degradation due to truncation the truncation path length in the decoder must be longer than that required for the original low-rate code.

In [10], the performance of different convolutional code generator polynomials with constraint length 7 in relation to OFDM is examined, with the key performance metric being BER in AWGN and PAPR. It is noted that industry standard for a generator polynomial of length 7 is – (7, [171, 133]) as this gives the maximum free distance [10]. In their work they show the BER performance against all possible generator polynomial combinations (101 to 177 octal) for the worst noise condition 0dB – fig. 7. The different regions show that there are some codes which have better BER performances i.e. the blue regions and they also observed groups of pattern showing similar bad performance along the main diagonal which corresponded to identical polynomials. In summary the authors conclude the following: 1) not all generator polynomial how good FEC, 2) Identical polynomials show poor performance, 3) there are codes which exhibit FEC in low Eb/No but there are those which show high FEC such as the standard 171 133 polynomial.

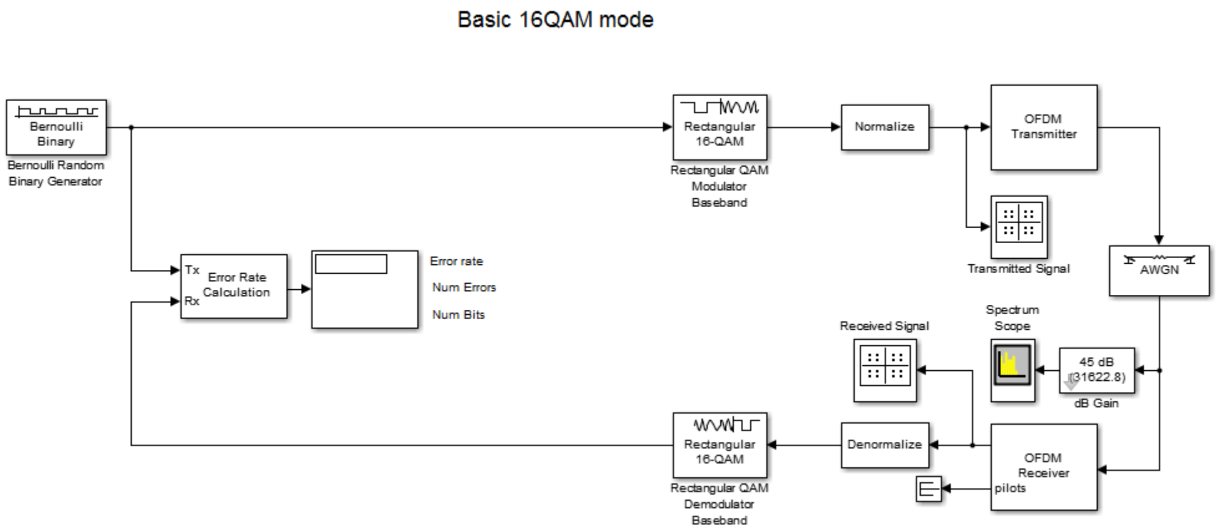
METHODOLOGY

MATLAB SIMULINK MODELS

The Simulation Block Diagram used was build for the HiperLAN/2 physical layer model, using the MATLAB & SIMULINK software package, where we modified for the Model A, B, C, D, E and F and its performance measured. The block diagram in Figure 1 represents the whole system model for proposed design.

MODEL A: Basic

This is the implementation of OFDM with a random seed generator which is modulated by 16-QAM and fed into the OFDM transmitter. It passes through an AWGN channel before the by filtered at the receiver and the reverse operations undertaken. This is a primitive form of OFDM with no convolution encoding, no puncturing, no interleaving and no channel. The basic model as a function of additive white Gaussian noise (AWGN) noise by the Signal-to-Noise (SNR) was altered within the AWGN block from approximately 35dB down to 5dB.

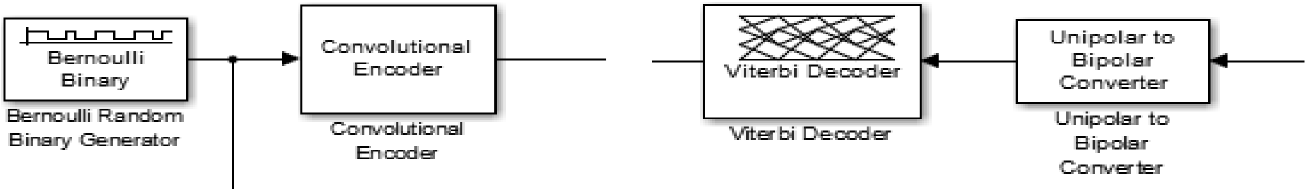


SNR(dB)	BER	SNR(dB)	BER
5	0.1816	13	0.02478
6	0.1582	14	0.01461
7	0.1359	15	0.007645
8	0.114	16	0.003487
9	0.09297	17	0.00134
9.5	0.08275	18	0.000419
10	0.0729	19	9.628e^{-05}
10.5	0.06337	20	1.574e^{-05}
11	0.054	20.5	4.629e^{-06}
12	0.03827	21	0

Table 1 – BER Basic channel

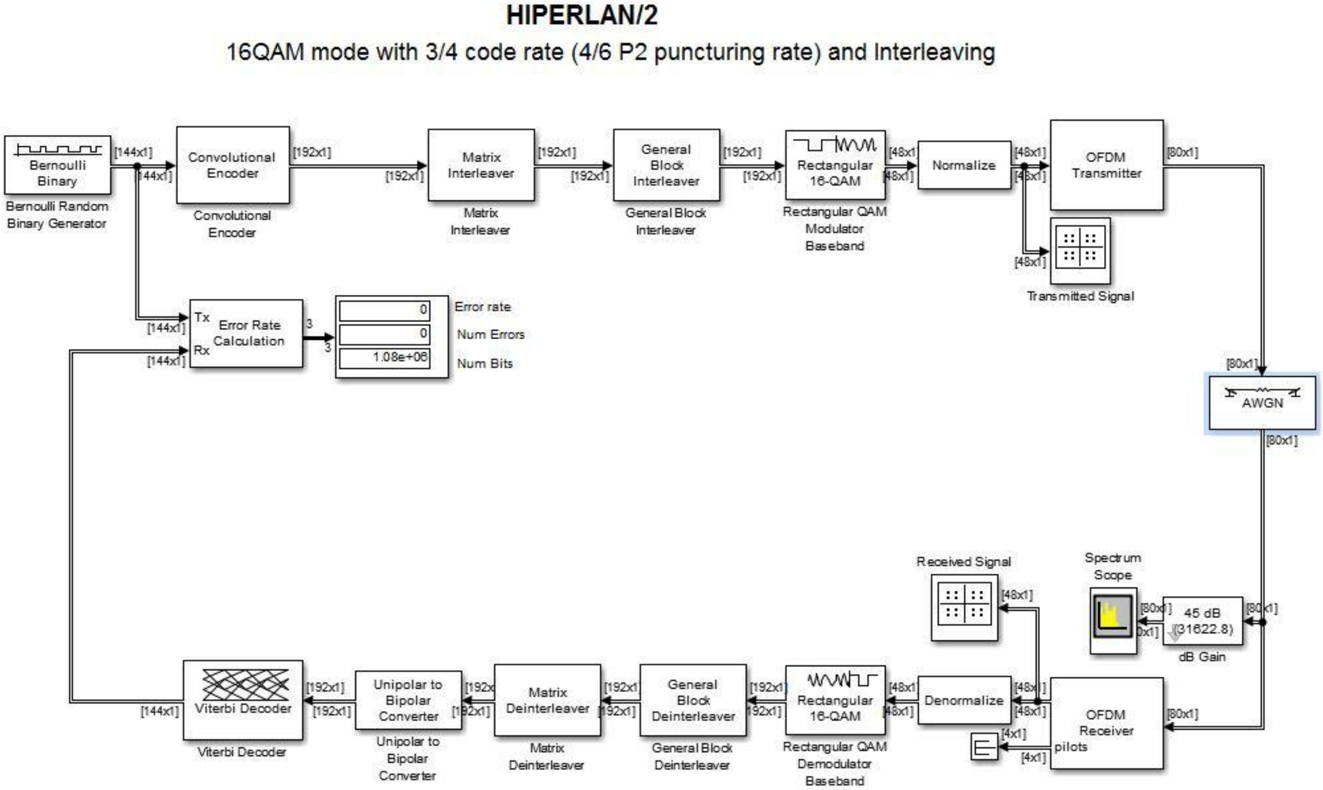
MODEL B: Convolution

(a) This hiperlan2 model includes convolution encoding, puncturing and bit and block interleaving.



Added features

In this secod part a convolution encoder and viterbi decoder have been incorporated and the BER perfromance has been re-evaluated.



Model C: Convolution Interleaving

This hiperlan2 model includes convolution encoding, puncturing and bit and block interleaving. In this configuration we have now incorporated interleaving in the system. Interleaving from digital communications can be described as the way we reorder transmission data in order to avoid burst errors. This greatly increases the ability for us to fix errors at the receiver using novel coding techniques

Model D & E: Convolution & Interleaving with Burst Noise

D model this is the hiperlan2 model with convolution encoding and puncturing, but now includes 2 subcarriers which are noisy (5dB SNR per subcarrier).

E model, this is the hiperlan2 model with convolution encoding, puncturing and bit and block interleaving, but also includes the same 2 noisy subcarriers as found in model D.

- In this set up the hyperlan2 model is implemented with convolution encoding and puncturing as in scenario B. However 2 of the subcarriers are isolated and noise is added to them before recombined and passed through the AWGN channel. This simulates impulse noise that would affect certain frequencies (subcarriers).
- The goal was to generate another BER curve with the 2 of the subcarriers having 5db noise added to them. Intuitively in this set up the information pertained in these 2 SCs should be adversely affected in spite of the increase in power when the signal is recombined and passed through the channel.

MODEL F: New Convolution Encoder

We implemented one different convolution encoder (poly2trellis) of the same constraint length along with its associated trellis decoding.

1. In this part we have the same set-up as in (c) – the only difference being that we implement a convolution encoder with different generator polynomials while keeping the constraint length the same. We chose to set the polynomials for the generator matrix to be equal to the same value as opposed to the default case where they are different.
2. In this part we are tasked at comparing the effect of changing the convolution encoder against the results obtained in part D (convolution encoding and puncturing, but now includes 2 SCs which are noisy).

DISCUSSION OF RESULTS

MODEL A: Basic

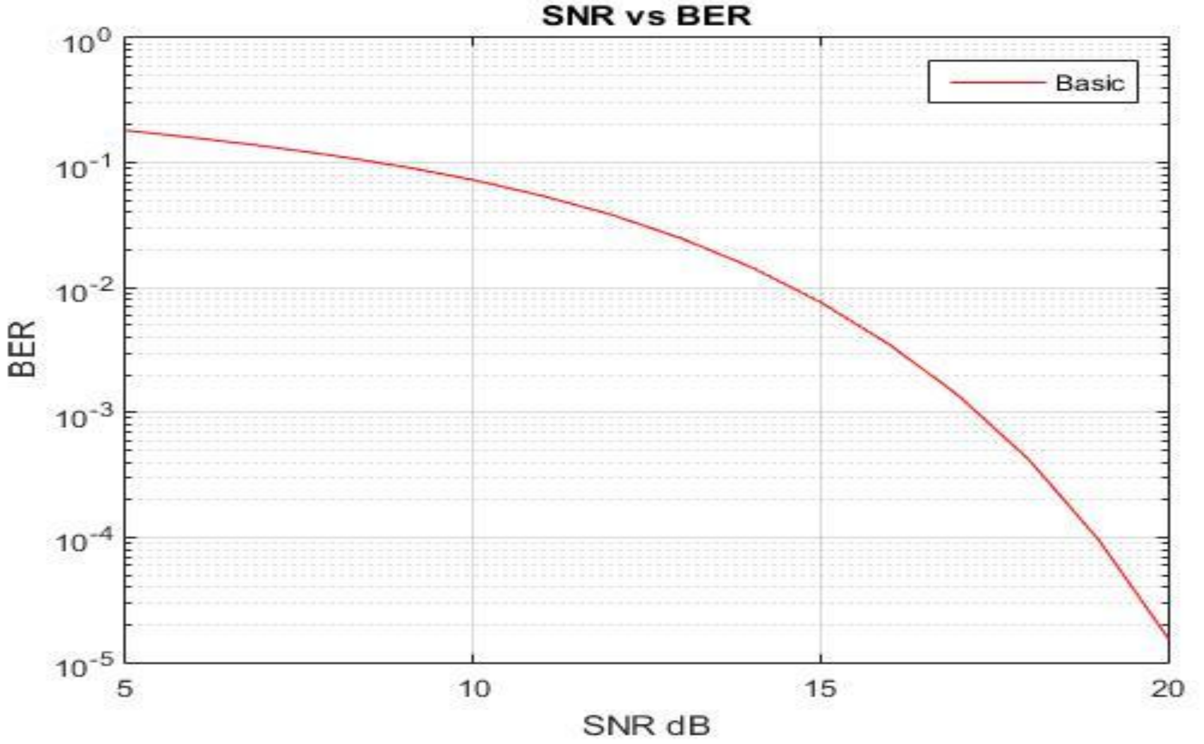


FIGURE 4: BER CURVE - BAISIC

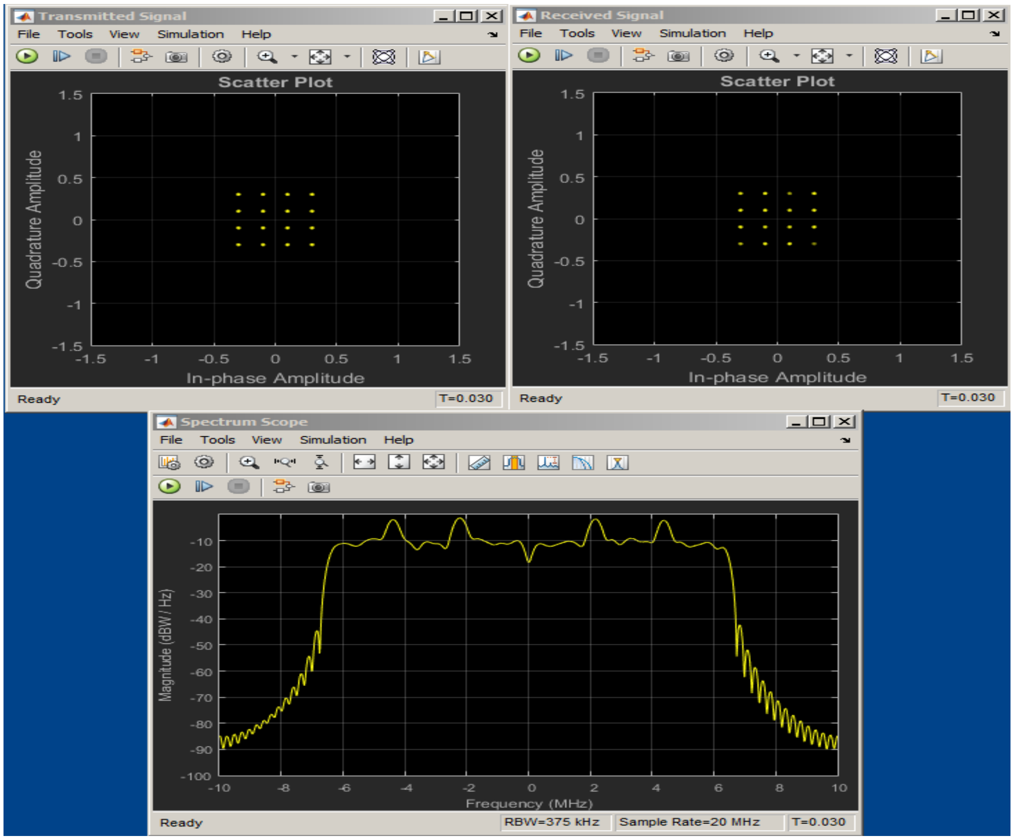


FIGURE 5: PLOTS

Our plots from Fig. 9 above was derived from table 1 which showed how OFDM behaves when only the receiver and transmitter are considered. To achieve a BER of 10^{-2} we would need an SNR of at least 14. Fig.10 above displays plots of the received and sent constellation plots and frequency response of an ideal communication system, whereby a perfect constellation plot is established with the decision boundaries clearly distinguishable and the magnitude response showing few ripples. However in reality such high signal strengths are rarely reached, but will use this as a mode of comparison.

MODEL B: Convolution

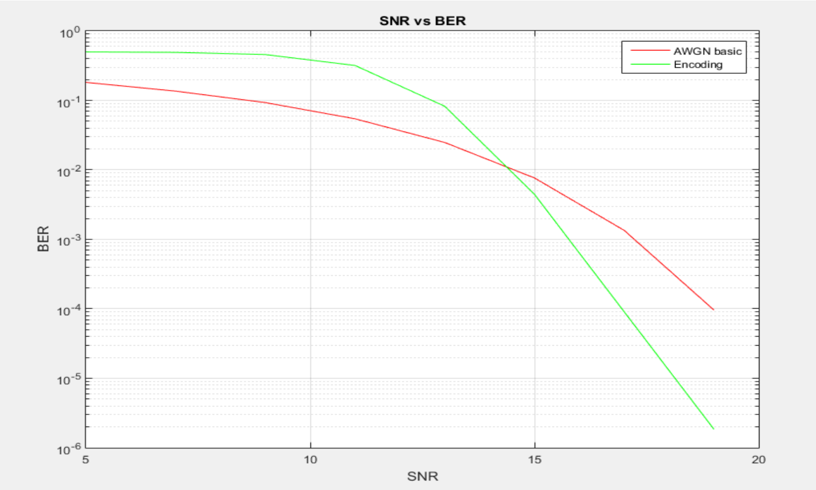


FIGURE 6

- An SNR of 14 marks an inflection point where the two graphs cross over
- At lower SNR (below this inflection point) - the basic channel exhibits less errors
- At higher SNRs the encoding scheme is able to obtain better BERs.
- At lower SNRs the basic outperforms the encoding – this is due to the fact that there is extra redundancy incorporated due to encoding. As such there are more bits which are affected by a lower SNR. However when the SNR is increased this redundancy enables us to reach much greater BERS as they possess extra information enabling us to recover signals even in the presence of noise.

MODEL C: Convolution Interleaving

One of the big advantage of the interleaving process is it does not require any bandwidth. There are many type of the interleaving used for specific purposes [4][13].

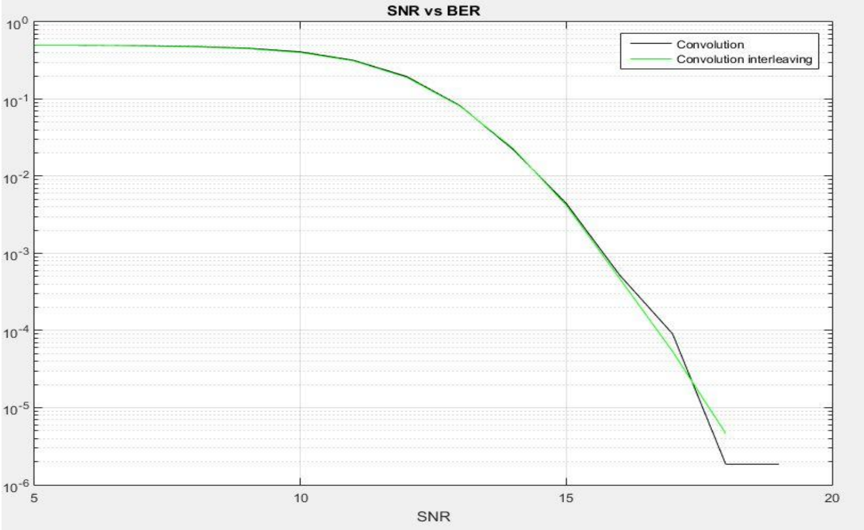


FIGURE 7: CONVOLUTION INTERLEAING AGAINST CONVOLUTION

It is largely evident from fig.14 that the disparity in performance between the interleaved and non-interleaved case is quite small when general noise is considered. Their performance is identical for low SNR up until we reach an SNR of ~ 14.5. Here we see the interleaved case outperform the other offering slightly better BER performance. At an SNR of approximately 17.36 the graphs intersect after which the non-interleaved case produces higher BER performances. Intuitively interleaving has an optimal performance after which no alternative form of interleaving will produce any further performance improvements.

However this experiment does not simulate burst errors so the advantage of utilizing interleaving is not witnessed. What this experiment does prove is that interleaving (which does not incorporate any further over heads in terms of bit transmission) does not impair the BER. It is identical at lower SNRS, and between SNRs of 14 and 17.5 it slightly exhibits lower BER to its counterpart. This in correlation with the literature we have reviewed thus far, in [7] the authors review extensively the technique of interleaving and discuss all the various designs. They also state that this technique is irrelevant when there is no burst error. The essence of interleaving is to make burst noise appear random by ‘shuffling’ the date. In this case, the noise is already random and has no busty elements as such the delays introduced by interleaving will only degrade the system performance without offering any improved benefits.

MODELD & E: Convolution & Interleaving with Burst Noise

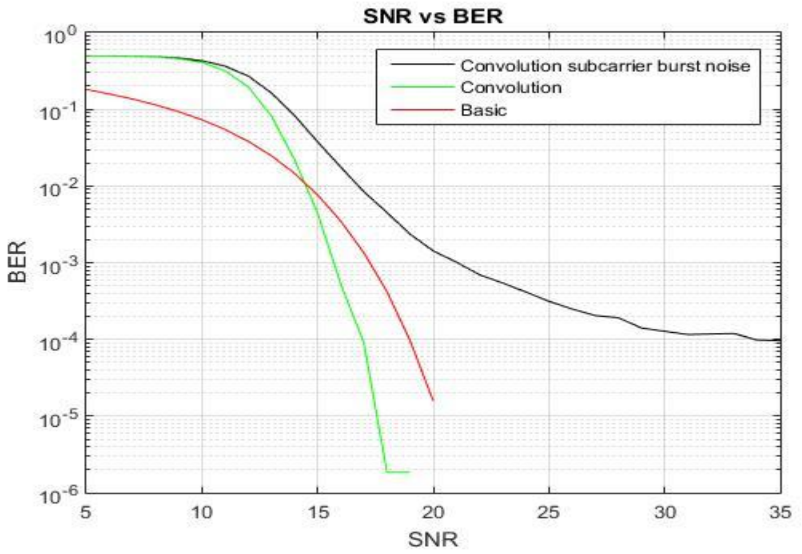


FIGURE 8: AFFECT OF IMPULSE NOISE

- In fig.16 for low SNRs (<11) we see that the effect of impulse noise is negligible on the system behavior when we compare 'convolution' against 'convolution SC with burst noise'. This is naturally intuitive as at low SNRs the noise power is similar to the signal power so the entire channel is flooded with noise, reshuffling the SCs will have no effect as all the channels are equally affected.
- As we increase the SNR further up to 16dB for instance we now see a clear deviation from the typical system performance. When the BER~10^{-2}, the bust noise case has SNR~ 16 while the other two cases coincide and have an SNR~ 14.9. The difference in performance only increases from this point onwards for the coded channel that does not experience burst noise.
- As we further increase the SNR (>16dB) other systems reduced errors and attain extremely low error rates. However in the case of the burst noise, it is important to note that the graph does not show a progressively increasing BER performance like the others. This is intuitive, despite the channel noise being negligible (at extremely high SNR) the system is still affected by impulse noise and information will still be lost by those particular SCs in spite of how much power the channel outputs.

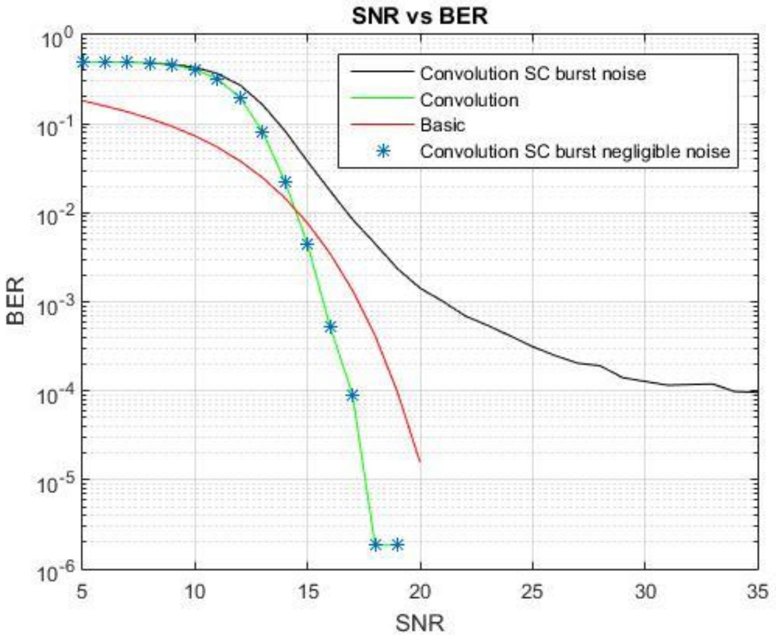


FIGURE 9: LOW IMPULSE NOISE

- In Fig.17 – to determine the effect of impulse noise we simulated the experiment again however the noise attributed to the 2 SCs is reduced by increasing the SNR to an arbitrarily high value (SNR=100).
- The results yielded identical results to that of scenario B, which suggested by adding little to no noise the information pertained in these SCs is unaffected. The only contribution is now just from the channel when the signal is recombined. Our experiment can thus be evaluated and prove that the system is noise limited by impulse noise at high SNR.

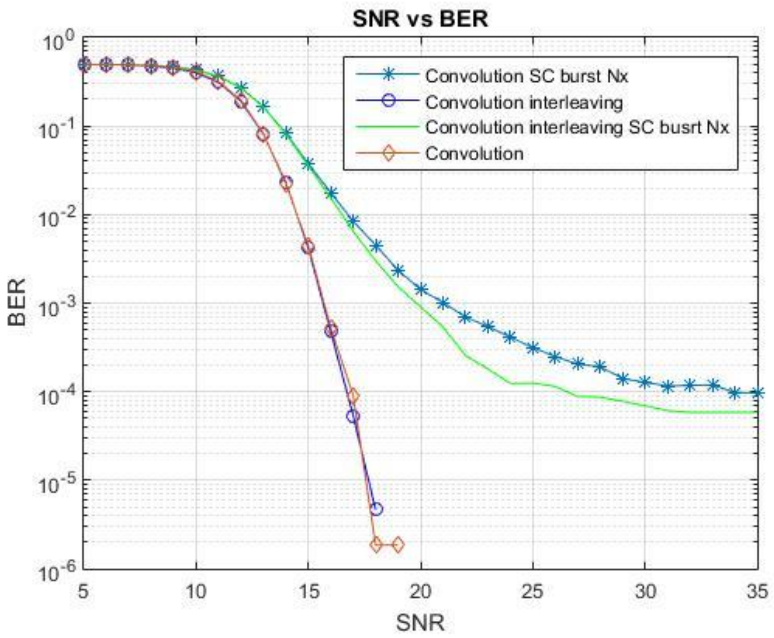


FIGURE 10

In this part of the experiment the same setup as that in D is configured, the only change coming with the fact that the subcarriers are now interleaved. The scenario was repeated for increasing SNRs. The results are shown in Fig.18 above:

- For SNR < 15 the convolution and the interleaved convolution with burst noise yield identical system performance. This means all the observed features from the previous section will also hold for the interleaved case at this SNR.
- When we being to increase the SNR > 15, we notice that the two systems (convolution & interleaved convolution) begin to diverge progressively. The interleaved case shows improved performance in contrast to its counter-part.
- At higher SNRs the burst noise can clearly be discerned amongst the remaining data. Interleaving spreads the user's data amongst all the SCs along the bandwidth. Those SCs which are affected by bust noise will now be spread across different users instead of affecting just the one user. This spreading of noise makes it appear 'random' and reduces its effect on the system throughput hence we can observe an improved BER performance when interleaving is utilized. If you consider the performance of the interleaved case alone when no bust noise is present it is almost identical to that of the case non interleaved case for the same considerations. When no bust noise is present the advantages of interleaving are not showcased, however the opposite is true when burst noise is present as is the case here.

Despite interleaving the system will not follow the same behavior of that in the case where burst noise is not present. In spite of how much we increase the SNR, the systems will always yield erroneous results within the data. In the case where the SCs are not interleaved the maximum achievable BER is ~ $10E^{-4}$after which a further increase in SNR does not yield better results. In the alternative case this threshold is set at $\sim 8.9E^{-5}$. Based on these results, it is thereby justifiable to state that when SCs are interleaved they can attain a maximum performance which is nearly 10 times greater (in terms of BER performance) against burst noise than when they are not interleaved.

MODEL F: New Convolution Encoder

I. In this part we have the same set-up as in (c) - the only difference being that we implement a convolution encoder with different generator polynomials while keeping the constraint length the same. We chose to set the polynomials for the generator matrix to be equal to the same value as opposed to the default case where they are different.

In Fig.19 below – the BER maintains a relatively flat line with a maximum deviation of 0.0675 until an SNR of 20 is reached, after which the graph sharply drops tending towards 0. Upon increasing SNR we note that no further decrease is observed, our BER remains at 0 and does not yield any lower values. This is far from optimal behavior and not what we aim to achieve; an increase in power does not yield a corresponding improvement in performance. The poor performance can only be attributed to the behavior of the polynomials we have utilized.

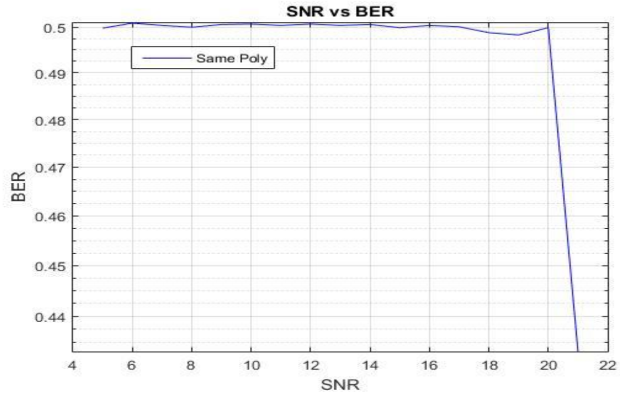


FIGURE 11: DIFFERENT CONVOLUTION ENCODER

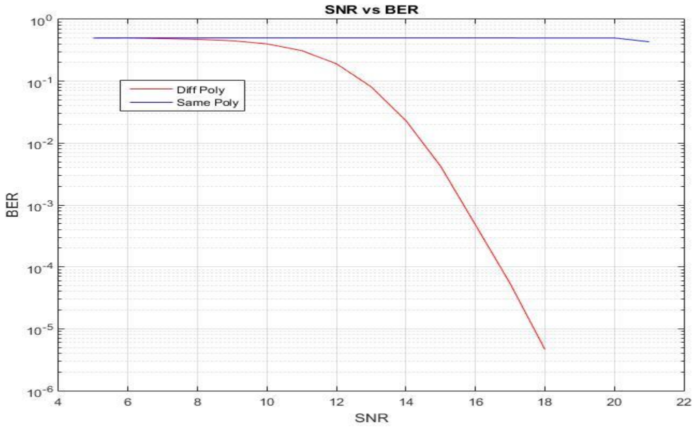


FIGURE 12: EFFECT OF THE GENERATOR POLYNOMIAL ON BER

When we compared our new convolution encoder to that of the previous case (Fig. 20) we can observe a notable difference. The new polynomial generator matrix has a flat response to SNR i.e. the SNR is relatively constant at 0 with a maximum deviation of 0.5007. In contrast the previous convolution encoder which has different polynomials in its generator function exhibits a typical BER behavior. It exhibits a BER performance that improves logarithmically with an increase in SNR. This is in correlation with the literature in [10] where the authors also investigated the effect of all the possible polynomials on the system. In their work they concluded that identical polynomials will display poor BER performances, however there are polynomials such as the standard (171 133) which will show optimal performance, thus evaluating the results we have obtained here:

II. In this part we are tasked at comparing the effect of changing the convolution encoder against the results obtained in part D (convolution encoding and puncturing, but now includes 2 SCs which are noisy).

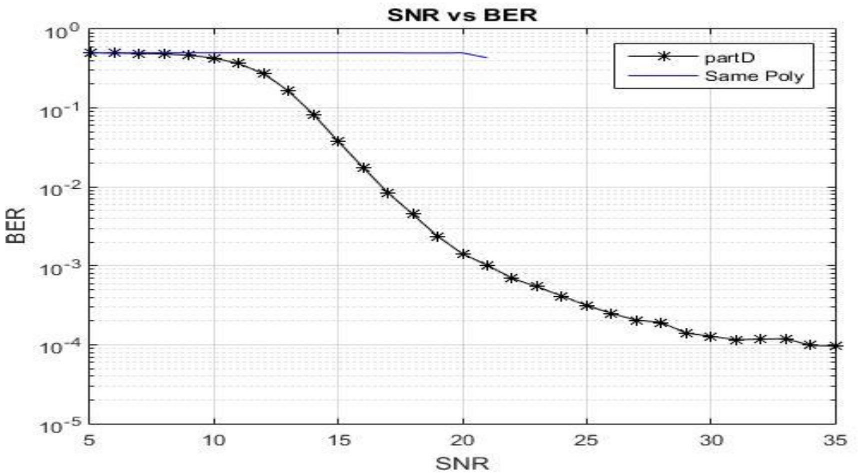


FIGURE 13

As we have previously discussed at length regarding the behavior of the new polynomial. It exhibits a flat line response and no further decrease in BERs after SNR is increased further. Part D – also mentioned previously is adversely affected by SC noise which limits the system performance. The only thing these systems have in similar is that they both have a limiting factor in spite of how much we increase the SNR.

CONCLUSION

By comparison of A and B, we find that a coded system out performs a non-coded system; this is what we would expect as the addition of redundancy allows us to rectify nearest neighbor problems. From our results we find that for optimum performance (SNR ~ 18dB) the coded system is able to obtain fifteen times better performance. On contrasting B and C, we see a negligible difference in BER performance when we incorporate interleaving to a system which is experience no burst noise, it is also noted that interleaving introduces delay so negatively impacts the system in that regard. However, when burst noise is present in E, the benefits of interleaving are evident. It was found that against burst noise, interleaving will yield ten times better performance. In part F, identical polynomials will exhibit the worst performance, while there are other combinations such as the standard (171 133) which will have good performance at low SNR. Among those there are those polynomials which will have poor performance at low SNR but improve with better SNR

FINAL REMARKS

If we can guarantee low BERs even under noisy conditions then we can design system which are very versatile, one such system is the wireless HIPERLAN/2 (High performance radio local area network). Wireless has many difficult challenges such as multipath, fading, interference and noise that will impair the system. Through innovative methods such as those implored by OFDM, interleaving and FEC we are able to handle the difficult conditions of wireless. Convolutions codes, encoders and decoders were found to provide power FEC capability allowing us to achieve even lower BERs – which in turn will allow us to utilize a higher modulation and offer those high data rates demanded by 3g cellular networks. Burst noise can adversely affect the system performance, Interleaving has been introduced to try and mitigate the affect. Despite the clever way it approaches this problem, the system still reaches a threshold after which further increase in SNR will not increase the BER. We can only reduce the impact of burst noise, but OFDM allows for frequency selective modulation, we simply use a lower modulation in those areas where burst noise is evident. With all the benefits of convolution it is still adding redundancy which needs to be managed as bandwidth utilization is an ever increasing concern, the trade off on bandwidth vs code rate is one that needs to be carefully considered before deciding on the system parameters. We have also observed that the polynomials must also be well considered as they can affect the system catastrophically in the case where they are identical. Overall we have shown; a thorough understanding of the principal of wireless digital communication, we have critically evaluated the performance of appropriate digital communication system components, and have demonstrated our ability to design alternative system components.

REFERENCES

1. J. Khun-Jush, P. Schramm, G. Malmgren and J. Torsner, (2002). HiperLAN2: broadband wireless communications at 5 GHz, *Communications Magazine, IEEE,* vol. 40, pp. 130-136.
2. S. Weinstein and P. Ebert, (1971). 'Data Transmission by Frequency-Division Multiplexing Using the Discrete Fourier Transform,' *IEEE Trans. Commun.*, vol. 19, pp. 620–34.
3. Y. Chiu, D. Markovic, H. Tang, N. Zhang, 'OFDM Receiver Design', EE225C. Final Report. Fall 2000. 12/12/2000.
4. Ian A. Glover and Peter M. Grant, 'Digital Communications', Text Book 3rd ed. Pearson Education Limited
5. J. G. Proakis, (2001). Digital Communications, 4th Edition, McGraw Hill. ISBN: 0072321113
6. S. Bawane, V. V. Gohokar, 'Simulation of Convolution Encoder', IJERT: International journal of Research in Engineering and Technology, eISSN: 2319-1163| pISSN: 2321-7308
7. Shi, Y.Q.; Xi Min Zhang; Zhi-Cheng Ni; Ansari, N., 'Interleaving for combating bursts of errors,' in *Circuits and Systems Magazine, IEEE* , vol.4, no.1, pp.29-42, First Quarter 2004
8. A. Calhan, C. Ceken, I. Erturk, (2007). 'Comparative Performance Analysis of Forward Error Correction Techniques Used in Wireless Communications'
9. Yasuda, Y., Kashiki, K. and Hirata, Y. (1984). High-Rate Punctured Convolutional Codes for Soft Decision Viterbi Decoding in Communications, IEEE Transactions on , vol.32, no.3, pp.315-319.
10. A. Vallavaraj, B. G Stewart, D. K Harrison, F.G McIntosh, 'Optimizing the Rate ½ Convolutional Code for OFDM Applications in terms of Bit-Error-Rate and Peak-to-Average Power Ratio', March 2006, pp. 1-6.
11. Ali CALHAN, Celal CEKEN, Ismail ERTURK, (2007). Comparative Performance Analysis of Forward Error Correction Techniques Used in Wireless Communications
12. Hun-I Kuo, Chi-Huang Shih; Ce-Kuen Shieh; Wen-Shyang Hwang (2010) 'A Fast and Efficient FEC Enhancement Scheme for Delay Sensitive Video Transmissions' pp. 252.
13. Ming-Fong Tsai, Naveen Chilamkurti, and Ce-Kuen Shieh (2010). 'Multipath Transmission with Forward Error Correction Mechanism for Delay-sensitive Video Communication', pp. 810-811.
14. Aghav Pandey, Ashwani Awasthi, Vikas Srivastava (2013). Comparison between Bit Error Rate And Signal To Noise Ratio in OFDM Using LSE Algorithm', pp. 463.