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Digital Predistortion (Dpd) Algorithm For 5g Applications

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Abstract

The emerging technologies and trends in the Wireless Networks applications have been enormously changing and expect to have the capability of very high data rates and speeds which maybe hundred times faster with high quality in connection and signal levels. With this advancement and growth of Wireless communication systems, there is a lot of demand for linearity in power amplifier. Also the Radio Frequency (RF) power amplifiers, which are expected to work with signals having Wideband Code Division Multiple Access (WCDMA) and are used extensively in Universal Mobile Telecommunication Systems (UMTS) for the generation of out-of-band emissions named as “Spectral regrowth”. As there is a need for enhancing the linearity and efficiency of Power Amplifier, the proposed work used the approach of Digital Predistortion. The proposed work of Digital Pre Distortion was developed using Matlab/Simulink combining memory polynomial algorithm. This developed algorithm was validated with various test cases and it was seen that the performance is improved drastically with high non-linearity with the memory polynomials order of 4 and 5 and having linear output. With the incorporation of memory polynomial digital predistortion in the proposed technique, the overall performance has been showing very good results. The overall improvement in the performance is observed by the incorporation of power amplifier with high non-linearity and thereby achieving less distortion with linear output.

Keywords:Power Amplifier, Digital Predistortion, Memory Polynomial, 5G

Introduction

Nowadays, wireless technologies have become most important technology than the wired technology. Linear and high efficiency Power Amplifiers (PAs) are important components in wireless systems. The power amplifier is the active element located between the antenna and the transmitter signal circuitry [1]. The PA is the element which uses the low-level RF signal and improves its power, without adding any change to modulation format, or other factors. In modern telecommunication systems, the Radio frequency PA’s that are working with the signals having wideband like WCDMA employed in Universal Mobile Telecommunication Systems (UMTS) are likely to possess spectral regrowth which infers out of band emissions [2]. The most efficient way is to maintain within the linear portion of the operating curve and to inverse the amplifier input level. This method is simple and have the disadvantages of larger size and higher cost. Another method is the Feed forward method for linearizing the power amplifiers in which the distortion is subtracted at the output [1]. This involves a considerable increase in cost due to high power analog combining network.

Another method, known as Linear Amplification with Non-linear Components (LINC), which generated the two phase-altered nonlinear PAs output to complete linear operation but may still need a high-power analog combining setup. Alternate way and one of the popular approach is to use the Digital Predistortion before the amplifier to reduce the effects of nonlinearity. The Digital Predistortion incorporation has led to several benefits decreasing cost and size as compared with other approaches. One of the commonly used technique to identify the parameters of a pre-distorter is the Indirect Learning Architecture (ILA).

In this paper, the main focus is on memory models that have effective wideband DPD. Firstly, we discuss the general process using Volterra Series method and then map out some simple special cases of memory models which consists of non-linearity coefficients and memory polynomial coefficients.

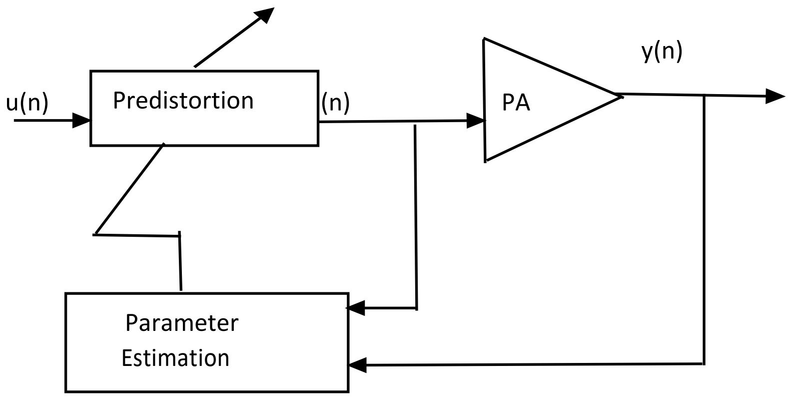


Fig.1. Generic Predistortion Scheme

Related Work

- **Morgan et.al [7]:** In this paper work, standard Radio Frequency Power Amplifier which are working with signals having wideband, like WCDMA in the UTMS is inversed correspondingly from their power level in order to reduce out of band spectrums. Adjusting these values of amplifiers to operate in wideband therefore it needs higher cost and larger size that would be needed for the similar power output. Another way that is attaining attention in wireless communication and have widespread demand, in order to use digital predistortion before the amplifier to decrease the effects of nonlinearity, thus by having low spectral regrowth it runs closer to maximum output power. Memory effects have included in the recent improvements to the technique in the model of predistortion that is important as there is an increase in the bandwidth. These wideband predistortion model leads to the GMP (Generalized Memory Polynomial) which integrates the cross terms of memory polynomial between the signal and leading or lagging terms.
- **Yasunori Suzuki et.al [8]:** In this paper work, configuration of Massive MIMO power amplifiers for transmitter is proposed. The configuration that is proposed in this work comprises of the path having linearity and amplifier corresponding to the loop of feed-forward design where the signal cancellation

takes place. The amplifier path contains the power amplifier and vector regulator while the linear path contains the delay line. In this paper 5G wireless communication system for Massive MIMO has been suggested. In Massive MIMO transmitter a decrease propagation loss and provides gigabit data transmission in high frequency band occurs due to the creation of narrow beam. Other than this the Massive MIMO is needed to be small enough as WI-FI access because it is developed in small cells that are presented in hotspot areas. The Massive MIMO transmitter is favorable in using the active and adaptive antenna technologies to fulfill the specifications that are mentioned in the paper work.

- **Jianxin Jing et.al [9]:** In this proposed paper, a technique named Digital Predistortion is proposed which is employed to linearize the target beam restricted with other beams in the multi-beam scenario of 5G Massive MIMO transmitters. The proposed paper models the interference signal first and then creates the exact opposite signal and both the signals gets cancelled. The results says that the digital predistortion technique operates really well to realize the target beam linearization, thus having lot of advantages for multi user applications in 5G Massive MIMO systems. Massive MIMO multibeam systems combined with passive beamforming network have been studied due to its simple structure, low cost and low power consumption.
- **MouradDjamai et.al [10]:** In this paper work, the RF power amplifiers that have nonlinear model is an important concept in the development and designing of linear amplifier. A predistortion technique based on DSP circuit is introduced and the continuous time model defining the power amplifier that is related to the quadrature modulation and quadrature demodulation method is identified. The model is designed with two models, the first one is modelled by using polynomial functions which uses nonlinear phase and amplitude distortion and the second one is description of the power amplifier dynamics referred to the MIMO continuous filter. The parameters are identified by using a method based on pseudo random binary sequence and output error as excitation of the signal. Power amplifiers are one of the significant components in the wireless communication systems. In order to transmit the amplified and modulated signals power amplifiers are needed. In order to decrease the power consumption and increase the efficiency of the power amplifier they are needed to be operated in the saturation region. In such scenarios there may be a possibility of nonlinearity in the power amplifier. The nonlinear signal components like spectral regrowth caused by the power amplifier are created which interferes the adjacent channels and bit error rate is also increased due to distortions.
- **Dian Xie et.al [11]:** In this work, LMS (Least Mean Square) and RLS (Recursive Least Square) algorithm combined with an improved adaptive algorithm is represented. The results give the comparative simulation to the mentioned algorithm. By using this method there is a decrease in the calculation amount which gives convergence stability and also achieves a good linearity performance.
- Compared to the various methods of linearization, one of the most cost effective method is the digital predistortion because of its better stability, adaptability and its implementation, stability. To calculate the coefficients of the power amplifier model adaptive algorithms are employed like memory polynomial model and Volterra model. Both RLS and LMS are adaptive algorithms. LMS algorithm have less computation and stable convergence whereas RLS algorithm have higher convergence and less precision. Power amplifier models can be classified into two types: memory and memoryless. The memory model is for baseband signal while the memoryless model is for narrow band signal and is defined by Volterra series which is more complex to compute. Moreover, it makes unattractive for the practical application because of its large coefficient number in Volterra series and thus there appears some improved model. The memory polynomial model, which is an enhanced version of Volterraseries

is employed in digital predistortion algorithm to remove the nonlinearity effects in the power amplifier.

- **Varahram et.al [12]:** In this work paper, the application of digital predistortion in baseband signal is a technique used for power amplifier linearization in order to decrease the ACI in the systems which have different modulation techniques like MQAM, OFDM etc, is employed. To linearize the power amplifiers digital predistortion is the best way because of its less cost effective and most architectures presume that memoryless nonlinearity is present in the power amplifiers. For applications like W-OFDM and WCDMA that has wideband signals the memory effects cannot be ignored. A new adaptive technique of DPD that involves memory effects of the power amplifier. This approach is combination of two methods, slope dependent method and memory polynomial predistortion. This new approach is examined by employing a 1.9GHz 60W LDMOS power amplifier with two or three carrier CDMA.
- **Bondar et.al [13]:** In this paper work, a new approach of digital baseband predistortion technique of wide band with improved power amplifiers and high memory quality is presented and investigated. By computing the iterative digital baseband technique distortion compensation can be increased. The memory effects are decreased by frequency- domain equalization in baseband. Different methods of modulation are employed in communication systems where increase in efficiency of spectrum leads in increase of PAPR and therefore, needs a power amplifier. Hence, linearizing amplifiers is becoming interesting research. From all the methods of linearization more concentration is given to DPD as it gains performance of good linearization without extra radio frequency components. A successive method in solving this problem is employing predistortion method. The first thing can be made is to minimize the effects of memory using DSP at baseband. An alternate is the overcoming distortion compensation by applying suitable iterations until the sequence leads to zero or until linearity is achieved.
- **Mahmoud Abdelaziz et.al [14]:** In this paper work, reduced complexity DPD solution is proposed. The proposed DPD removes the unwanted distortions due to in-phase and quadrature modulator impairments and power amplifier nonlinearity in un the transmitters are reduced by using the bandwidth that is reduced by filtered basis functions. However, the estimation of parameters in DPD is based on reduced bandwidth observation thus, by decreasing the overall complexity. In Massive MIMO systems the digital predistortion can be used with large number of radio transmitters and receivers and power amplifiers are employed where decreasing digital predistortion complexity is very hard. However, estimation of closed loop parameter solution is constructed on decreasing the bandwidth of the power amplifier output signal that is combined with simple correlation preprocessor. In the earlier context the filtered basis function was used in ILA where only the nonlinearity of the power amplifier is considered.
- **Xin Liu et.al [15]:** In this work paper, BO-DPD (Beam Oriented Digital Predistortion) method for linearizing the power amplifiers is proposed which uses the Massive MIMO technique of hybrid beamforming at the transmitters, which gains linearization in the direction of main beam of the transmitted signal and the issue of hybrid beamforming array is reduced by implementing the digital predistortion. In Massive MIMO hybrid beamforming, the digital predistortion implementation is not suitable to linearize the power amplifiers because digital chains numbers are lesser than power amplifier numbers that are used. Moreover, the beam oriented digital predistortion can solve the problem by linearizing and constructing the signal of virtual main beam instead of the single power amplifiers. As per the weights of beam forming for the array elements, the output of the power amplifier to make an estimate the main beam for digital predistortion is combined with the feedback

path. An average estimation technique is proposed to enlarge the range of the linearized angle in the direction of main beam

- **Lei Ding et.al [16]:** In this paper work, the RF power amplifiers uses a popular method called as digital predistortion which is the used very widely in the current scenarios. In order to linearize the power amplifiers, it is a cost-effective approach in various wideband signals due to this digital predistortion technique is employed which working with less out of band spectrums is called as spectral regrowth. The parameters are estimated in the digital predistortion in order to reduce the noise that is present at the output of the power amplifier. The final aspect of the noise is to reduce the digital predistortion performance resulting in high spectral regrowth. By applying the coefficient bias introduced by noise measurement model reduces the spectral regrowth. This paper proposes two methods for reducing these effects. The first method is to use the forward estimation followed by offline inverse noiseless estimation and the other one is to use a specifically designed frame averaging with periodic training signal. The spectral regrowth is reduced by 10dB is shown in the simulation results.
- **Jing Zhang et.al [17]:** In this paper, in the transmitter's part of the communication system power amplifiers are used which are inherently nonlinear device. To enhance the function of communication channels digital predistortion is employed to decrease the nonlinearities in power amplifier. But most of the architecture are based on the memory less power amplifier model. The signal of power amplifier in the transmission cannot be ignored while using memory effects and the memory less predistortion have the weak performance. In this work, a predistortion technique is analyzed which is applied to the wideband wireless transmitter and is done by indirect learning architecture is proposed. Then the performance is verified by simulation results of overall transmitter system. The measurement shows that good AM/PM and AM/AM performance is obtained when input is a single carrier Wideband Code Division Multiple Access signal with 5MHz bandwidth and after adding the proposed predistortion method approximately 20dB improvements out off band at a frequency offset of 5MHz is gained.
- **Raz et.al [18]:** In this paper work, Volterra filters are represented in the form of diagonal coordinate which is designed a utilized to define the effective Volterra filter implementation for processing input signals. The sum of filters that are linear that is applied to the input signals that are modified in the diagonal coordinate which is represented as the output. Hence, different methods of linear filtering are used to implement the nonlinear filter of the input in the baseband. Down sampling is employed to decrease the complexity of computation. The similar method is used to emerge efficient implementations for processing FDM input signals, PAM signals and continuous time carrier-based signals. There are two dominant methods which reduces the complexity of Volterra filter. In the first method using a cascade model which is contains memory less linearity's in series with linear filters in the Volterra filter is approximated. The cascade model outputs in the filter coefficients are nonlinear and hence defining the nonlinear problem of estimation in the filter coefficients. In the next method the product approximation which defines the Volterra kernel filter as a combination of linear products of simple basis vectors. The estimation of basis vectors is a problem of linear estimation and hence, conditions for uniqueness and optimality are established easily.

Power Amplifires

3.1 Functioning of Power Amplifiers

Power amplifiers (PA) are one of the very essential blocks in wireless systems, which are responsible of overcoming the loss between the transmitter and receiver. In order to achieve the adequate transmission power, PAs are most important in communication systems [1][5]. As the input power increases, high efficiency levels can be obtained.

However, PAs are inherently non-linear when they are driven in high power modes, and may lead to a trade-off among the efficiency and linearity. Moreover, latest techniques which are extensively used in various wireless industries due to their high speed of communication, that are controlled by is using non-constant envelope techniques. These techniques have high peak to average power ratio (PAPR) as the frequency of spectrum efficiency is increased. For linear transmission of the symbols with high peak power, the PA's average output power needs to be several dB lower than the compression point which decreases the overall efficiency [2]. Digital Predistortion (DPD) technique is widely used to overcome the problem of non-linearity. To overcome this non-linearity - high efficiency problem one of the widely accepted approaches is digital predistortion (DPD).

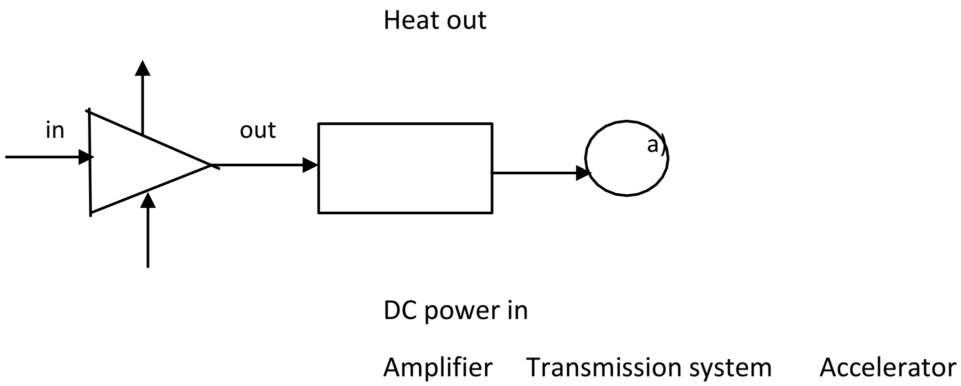


Fig. 2. Block diagram of Power Amplifier

The efficient power amplifiers exhibit an undesired nonlinear behavior as they are operating close to saturation, generating a distortion spectrum, which will be wider than the allocated channel [16] and this widening of the transmitted spectrum can be called as spectral regrowth. Polynomial functions of the carrier frequency are harmonics and polynomial functions of the digital modulation located near the carrier frequency are intermodulation.

In most RF transmitters, to limit the transmit bandwidth filter is placed after PA. The passband spans, typically, several channels.

The out-of-band and in-band distortions are regulated by specifications associated with the modulation format of the input signal. The distortion of the Out-of-band is measured by the amount of distortion power into adjacent channels neighboring the allocated channel. In general, the specifications make out-of-band distortion a key measurement of power amplifier linearity particularly for CDMA-based modulation formats [6]. The distortion of in-band increases the error vector magnitude (EVM). The EVM is the root mean square (RMS) difference between the demodulated signal prior to quantization and the desired digital signal. It is a key measurement within OFDM systems, particularly when the individual subcarriers are modulated using 64-QAM (quadrature amplitude modulation), and is degraded by impairments including power amplifier nonlinearities [22].

Power amplifier models are of three types:

i. Saleh Model

ii. Rapp Model

iii. Ghorbani model

3.1.1 SALEH MODEL

The Saleh model is one of the efficient and quasi-memory less model which uses four parameters for fitting the model to measurement data. Using the Saleh model, the improved estimation approach for modelling the power amplifier can be done and Saleh model is mainly used to model the DPD in wireless system and predicts the nonlinear distortion hence in this paper Saleh model is used. The methods of Amplitude-Amplitude as well as Amplitude-Phase functions are defined by the following set of equations,

$$g(r(n)) = \frac{\alpha_a r(n)}{[1+\beta_a] r(n)^2} \quad (1)$$

$$f(r(n)) = \frac{\alpha_\psi r(n)}{[1+\beta_\psi] r(n)^2} \quad (2)$$

where, $\alpha_a, \beta_a, \alpha_\psi, \beta_\psi$ are model's parameter

3.1.2 RAPP MODEL

The Rapp model models the amplitude distortion only and uses three parameters. This technique is quite simple to use and it adopts the performance of power amplifier to be linear until it reaches the saturation level. The amplitude-amplitude modulation conversion general expression is as follows,

$$g(r(n)) = \frac{r(n)}{[1+[\frac{r(n)}{O_{sat}}]^{2s}]^{1/2s}} \quad (3)$$

Where the parameter for setting the smoothness of the transitioning to saturation state from linear state is s and parameters for setting the output saturation level is Osat, the smaller the s the smoother the transition.

3.1.3 GHORBANI MODEL

In order to fit the model parameters, the Ghorbani model uses 8 parameters. This is same as the Saleh model but this model cannot be used to model the digital predistortion model. This model is also a simple and efficient quasi-memory less system which has its Amplitude-Phase modulation and Amplitude-Amplitude modulation conversions defined in the following equations,

$$g(r(n)) = \frac{x_1 r(n)^{x_2}}{1 + x_3 r(n)^{x_2}} + x_4 r(n) \quad (4)$$

$$g(r(n) = \frac{y_1 r(n)^{y_2}}{1 + y_3 r(n)^{y_2}} + y_4 r(n) \quad (5)$$

Where, x_1, x_2, x_3, x_4, y_1, y_2, y_3, y_4 are model's parameters.

3.1.4 3.1.4 PA MODEL IN MATLAB/SIMULINK

The power amplifier model is designed in the MATLAB/SIMULINK tool and the models are shown below.

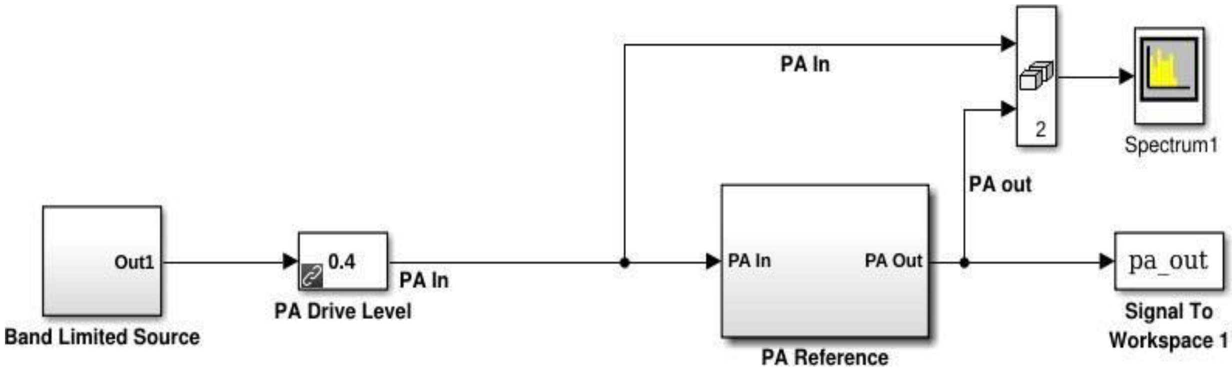
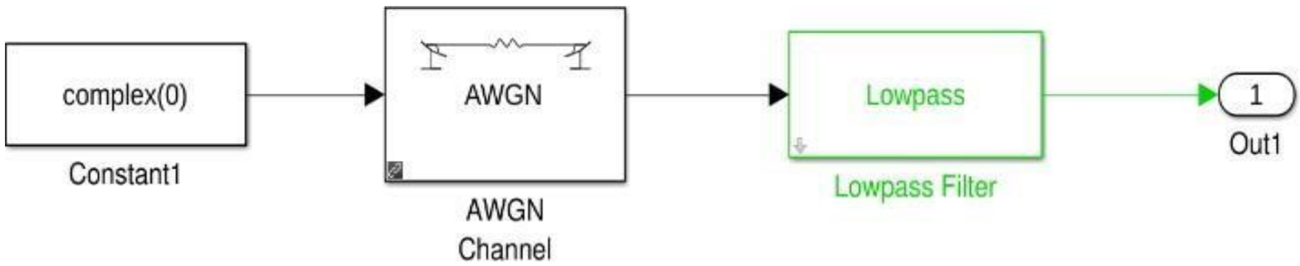
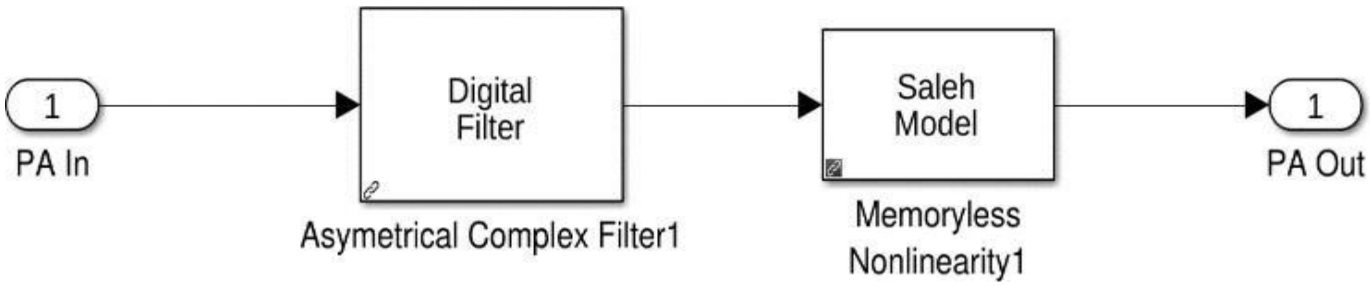


Fig. 3. (a) Simulink model of Power Amplifier



(b) Subsystem model of Bandlimited Source



(c) Subsystem model of PA reference

Fig.3. (a) illustrates the main Simulink Power Amplifier model which have the two subsystem models Bandlimited Source and PA reference model fig (b) refers to the bandlimited sources model and fig (c) refers to the Power Amplifer reference model.

The power amplifier model comprising of a Saleh amplifier in series with an asymmetrical complex filter as shown in fig (c). The excitation is an additive white noise (AWGN) signal that has been low pass filtered as shown in fig (b). The input and output signals are shown in below figure.

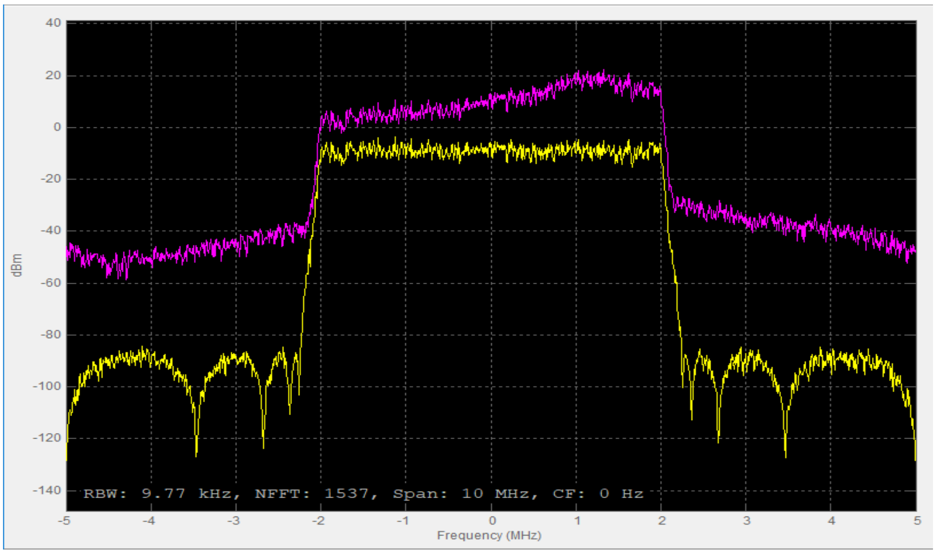
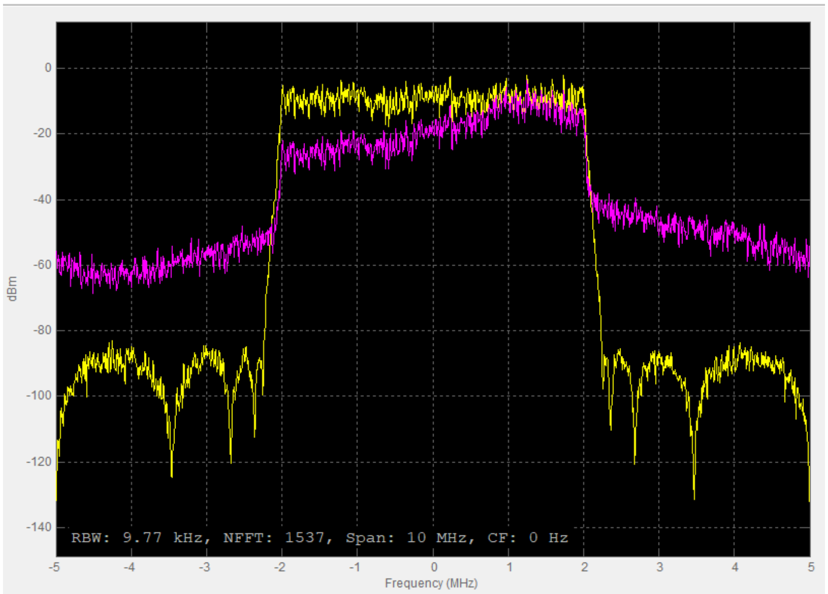
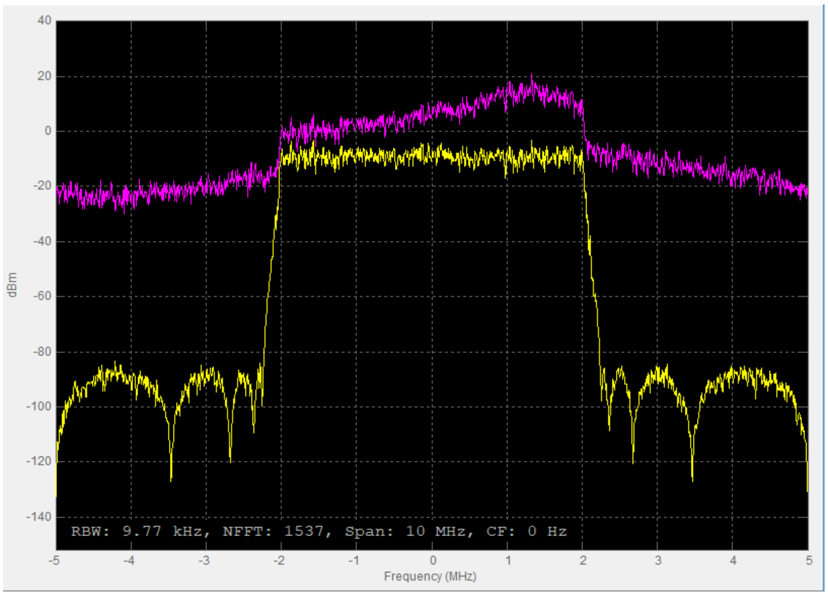


Fig. 4. (a) Simulation result of Power Amplifier with Saleh Model



(b)Simulation result of Power Amplifier with Rapp Model



(c) Simulation result of Power Amplifier with Ghorbani Model

From the above simulation results we can observe that the Rapp model output in fig.4. (b) becomes linear only at the saturation point. Hence the other part of the output will remain non-linear. In next simulation result of Ghorbani model in fig.4. (c) the output obtained is non-linear but this model cannot be used to model the DPD model. The Saleh model simulation result shown in fig.4. (a) gives the non-linear output where the output is not similar to input. In order to remove this non-linearity, we use DPD model and obtain the linear output. The Saleh model is mostly used in RF Amplifiers so in order to design the DPD Saleh model is designed.

3.2 Digital Predistortion

Digital Predistortion is an efficient approach for reducing the amplifier distortion. The predistorter linearizes the power amplifier by generating a non- linear transfer function i.e., inverse to the power amplifier in such a way that when it comes before the power amplifier the overall amplification of the system is nearly linear. Amplifier magnifies the input signal and generates a larger output signal [7]. Ideal amplifier will enhance the signal quality in the identical degree irrespective of the signal levels. This different amplification level depending on signal level results in the signal distortion which may cause several undesired outcomes.

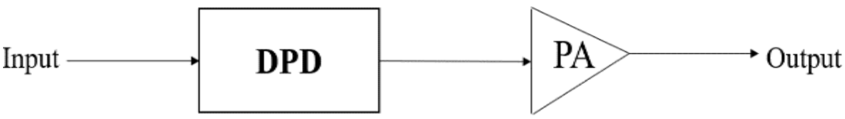


Fig.5. Digital Predistortion (DPD) block diagram

The block diagram of Digital predistortion shown in fig.5 is a technique to reduce the amplifier. The predistorter linearizes the power amplifier by generating a non-linear transfer function i.e., inverse to the power amplifier in such a way that when it comes before the power amplifier the overall amplification of the system is nearly linear [15] [13]. The generation of linear amplification is obtained as the Predistorter generates an inverse transfer function before the amplification. There are different techniques used in Digital Predistortion they are LUT based digital predistortion, memory less polynomial digital predistortion and memory polynomial digital predistortion. Memory less polynomial digital predistortion contains only the present input data and output depends only on the current input. The Memory polynomial digital predistortion contains both the current and previous input data and output depends both on the present and past input. In this paper Memory Polynomial digital predistortion algorithm [13].

3.3 DPD MODEL IN MATLAB/SIMULINK

The below figure. 6 illustrates the design of Model Digital Predistortion.

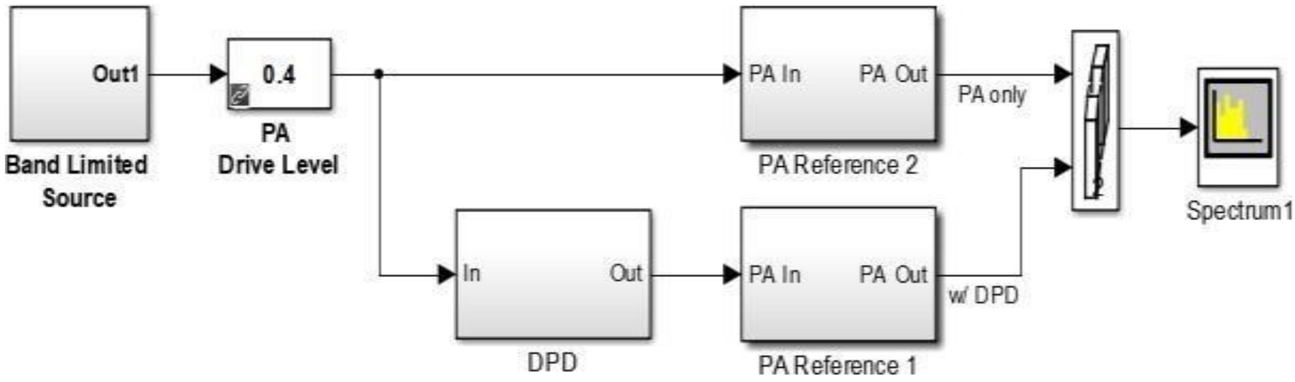


Fig. 6. Simulink model of Digital Predistortion

The Simulink model of DPD is same as the basic DPD as shown in fig.5. The DPD block is placed before the PA which generates the inverse transfer function for power amplifier in order to reduce the non-linearity. The detailed model of DPD is given in the next sections where the DPD is modelled using ILA and Memory Polynomial DPD Algorithm [8].

3.3.1 INDIRECT LEARNING ARCHITECTURE (ILA)

Firstly, it is introduced to instruct the neural network controllers and there after it is accepted for DPD generation [10]. ILA is most commonly used method to recognize the digital predistorter parameters. ILA is established on the inverse modelling technique, using output signal of the power amplifier to model the power amplifier input. Once the postdistorter of the power amplifier (also known as post-inverse) has been done, the post distorter parameters will be loaded to the same model used as the predistorter [11].

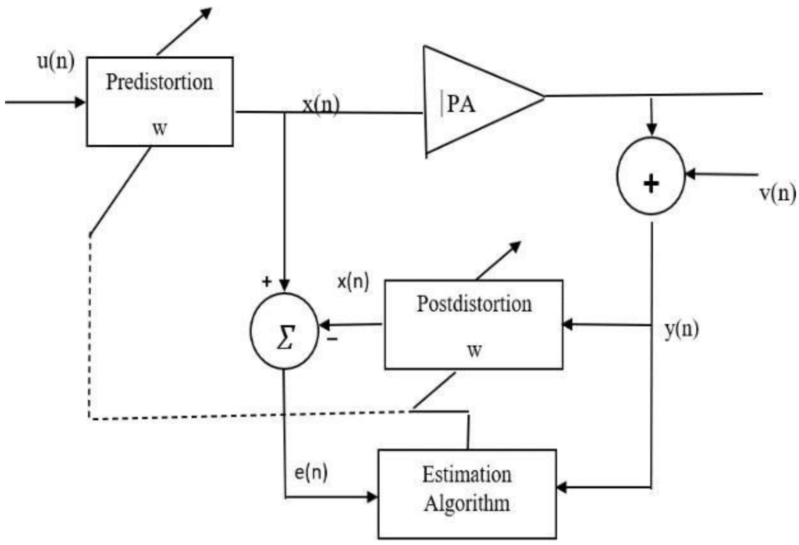


Fig. 7.Predistortion by Indirect Learning Architecture

The above figure 7 explains about the Indirect Learning Architecture of digital predistortion. The predistortion block is connected to the power amplifier, the input of the predistortion is given as u(n) and predistortion output is x(n). The output of the predistortion is inputted to the power amplifier, the power amplifier output along with the gain v(n) is added and is connected to the post distortion which is the copy of predistortion. In order to estimate the coefficient parameters, copy of predistortion called as postdistortion is introduced. In the block of Predistortion the Memory Polynomial algorithm is used. The below figure 8 shows the Simulink model of ILA which is also called as Adaptive digital predistortion the name adaptive because the power amplifier output is connected as input to the digital predistortion in feedback form and adaptive algorithm is used. Hence the name Adaptive Digital Predistortion [14].

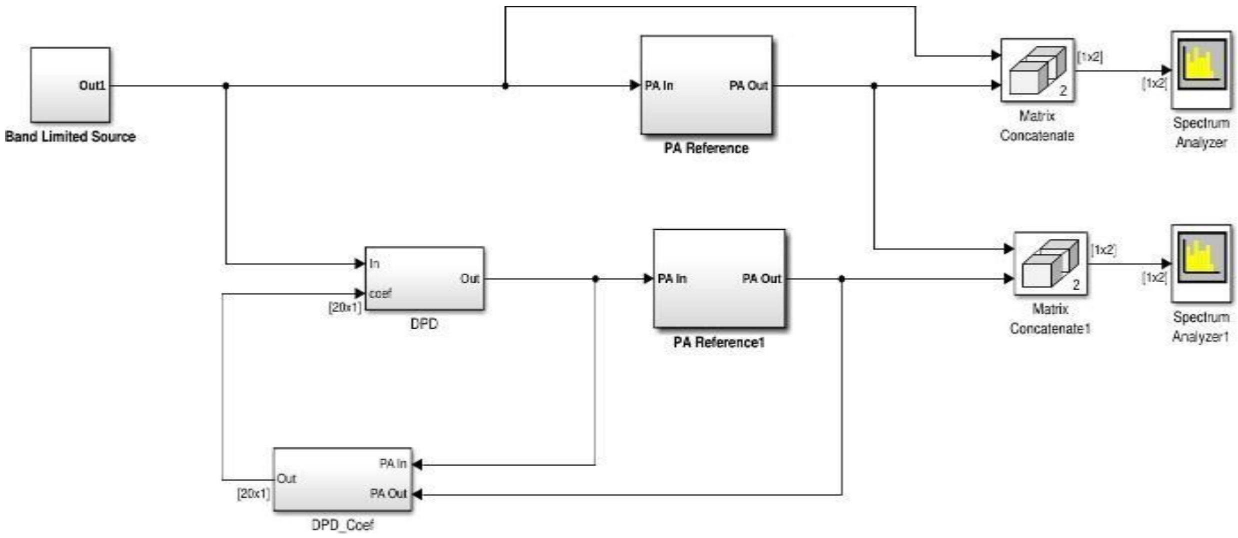


Fig. 8. Simulink Model of Adaptive Digital Predistortion

3.4 MEMORY POLYNOMIALS

Memory polynomial comprises of several function related delay taps and static functions of nonlinearity. It's a part of general Volterra series comprising of its principal diagram parameters which are the minimized.

Figure 1 represents the generic digital predistortion scheme, with u(n) being the input to the predistortion is u(n) whose output x(n) in turn will be fed to the power amplifier for generating the output y(n). The M-tap memory nonlinearity defined by Volterra series, comprises of sum of multi-dimensional convolutions which can be represented as

$$y(n) = \sum^{K} y_k(n) \qquad (6)$$

$$y_k(n) = \sum_{m1=0}^{M-1} \sum_{mk=0}^{M-1} h_k(m_1, .., m_k)^* \prod_{l=1}^{k} x(n - m_l) \qquad (7)$$

Where, is the k[th] dimensional convolution of the input with Volterra kernel h_k. It can be a general form of a power series represented with a finite memory of length M [8].

The generalized form of memory polynomial equation can be written as

$$y_{MP} = \sum^{K}{}_{k=1} \sum_{m=0}^{M-1} a_{km} x^k(n-m) \qquad (8)$$

For the narrow band case, if we choose the combinations of the $x(n)|x(n-m)|k-1$, we obtain at the Kims model[19], which is referred to as memory polynomial[20].

$$y_{MP} = \sum_{k=1}^{K} \sum_{m=0}^{M-1} a_{km} x^{k}(n-m)\, x\, (n-m)\, |^{k-1} \qquad (9)$$

This model of memory polynomial has considered to efficient in the case of predistortion of actual power amplifiers under some operating conditions.

The Simulink model of the memory polynomial DPD which is a subsystem of DPD is as shown in below figure 9 (a) (b).

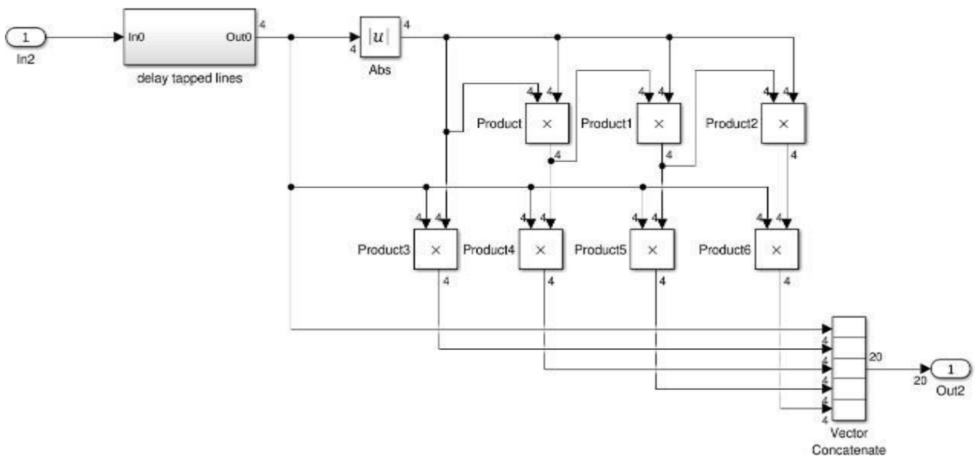


Fig. 9. (a) Simulink model of Memory Polynomial DPD

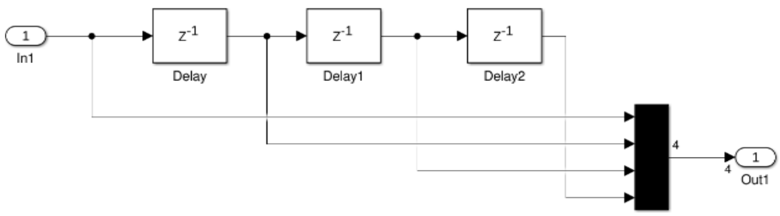


Fig. (b) Subsystem model of Delay tapped lines of fig (a)

Here in above figure 9 (a) and (b) the memory polynomial coefficients and the nonlinear coefficients are modelled according to equation (9).

3.4.1 ESTIMATION ALGORITHM

Various algorithms based on lest square are available to estimate the model coefficients which may be available as linear weightage of non-linear signals [6][18] which is the easiest way to formulate such a problem. Initially the coefficients are collected into one Jx1 vector and can named as “w”, with J being total number of coefficients. Every item of the coefficient vector w is mapped with a signal whose samples of samples for a period, say n = 1,2,….N, are accumulated into a vector. Combining all those vectors ina a matxi X of the size NxJ the output of the proposed model can be expressed as

$$y = Xw \qquad (10)$$

where$y$ is a Nx1 vector that represents an estimate of the vector y.

For the technique of predistortion which uses inverse modeling shown in figure 8 we can rewrite equation (10) as

$x = Yw$ (11)

where the input is an estimate of the sampled output and Y is constituted same as X with x(n- m). This is the actual estimate used predistortion based scenarios.

From fig. 8 the error of estimation can be written as

e(n) = X(n) – x(n) (12)

The block of N samples in vector form can be written as

e = X– x (13)

Now the least squares solution is simple to write which minimizes $||e||2$ as follows:

w = (YHY)−1YHx (14)

The inverse of JxJ sample covariance matrix can be represented as YH Y, and can be computed by obtaining linear equations solution as

YHYw = YHx (15)

From the above equations the Simulink model for estimation algorithm is modelled as follows

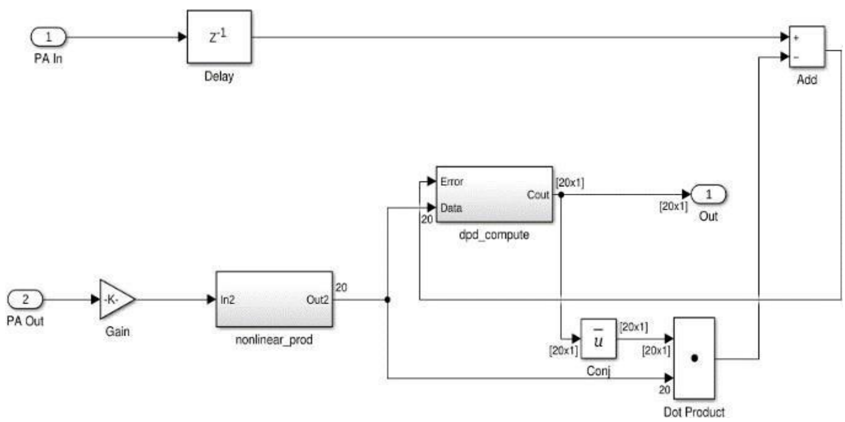


Fig. 10. (a) Simulink subsystem model of Dpd_Coef from fig 8

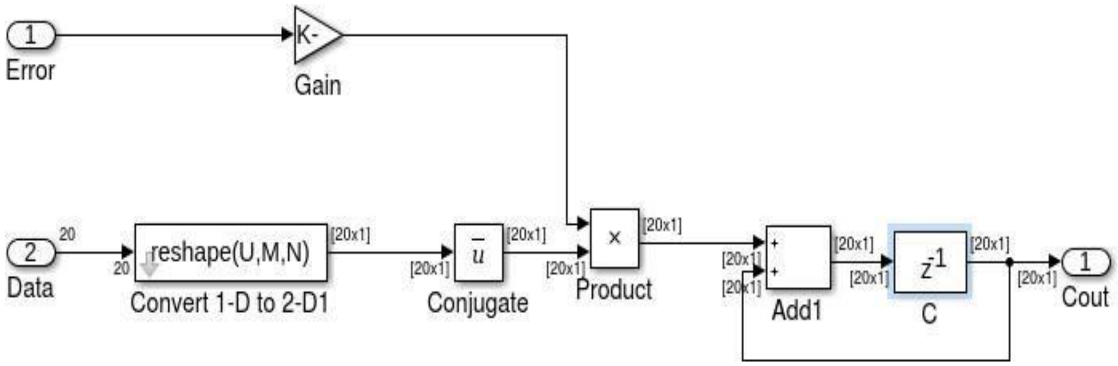


Fig. 10. (b) Simulink subsystem model of dpd_compute from 10(a) (estimation algorithm model)

Results

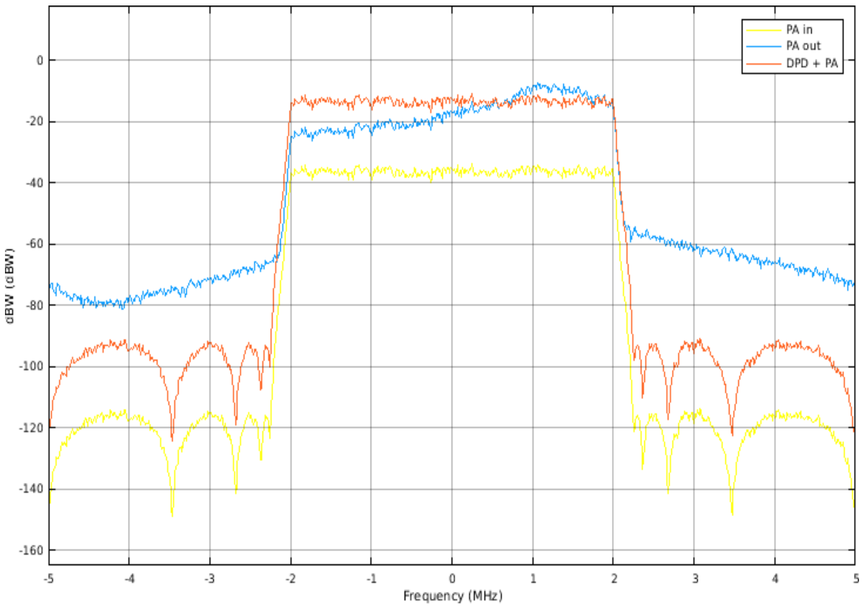


Fig. 11. Simulation result of Power Amplifier With DPD

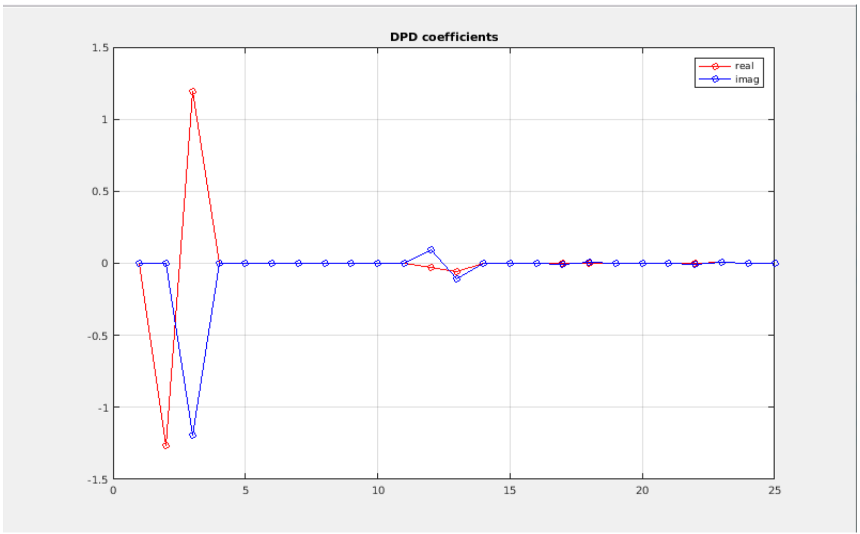


Fig. 12. Simulation result of Real and Imaginary coefficients of DPD

From fig 4 (a) and fig 11 we can clearly observe that the output without DPD have more signal distortion and output is not similar to input. From fig 11 we observe that output with is almost similar to power amplifier input and is linear. The output spectrum with delay taps order M = 4 and memory polynomial with nonlinearity order K = 5 with 20 coefficients in total gives the linear output. Hence the memory polynomial DPD algorithm is most preferable algorithm for wireless networks in order to linearize the power amplifiers.

Conclusion

Linear power amplifiers and high efficiency are vital factors in wireless communications Scenarios. Though there seems to be a trade-off among linearity and efficiency, the highly efficient power amplifiers will show some non-linearity and the power amplifiers with linear behaviour show lesser efficiency. To accommodate both the efficiency as well as the linearity requirements the digital predistortion is normally incorporated. The proposed work discussed in this paper has considered various aspects of the linear of Pas. The implementation of a predistorter has been done in two phases. In the first phase the pre-distorter model is designed and the parameters for this model is identified in the second phase. ILA technique have been chosen for the identification of the parameters and this ILA technique allows a greater impact and controlling of the output signal from the linearized power amplifier. The implementation has several challenges and one of them being addressing the memory effects by the power amplifiers for wideband signals or higher power amplifiers. Whatever combination of DPD function and estimator structure passes the specification with sufficient margin for the manufacturing process is acceptable.

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