Good afternoon, everyone. My name is Xiaoqi Yu, coming from southern university of science and technology. The topic of my presentation is “Deep neural network based stable digital predistortion using ELU activation for Switchless Class G Power amplifier. It’s have four parts: background and introduction, the proposed DPD algorithm, experimental validation and discussions and conclusions.

**1. Page 1**

\* Digital predistortion is a crucial linearization technique for power amplifier. Fig 1 show the fundamental principle and indirect learning structure of DPD in this paper. Implementing predistorter before PA, it mitigates the nonlinearity of PA by generating the pre-distorted signals.

\* Recently, back propagation neural network and its variations have attracted extensive research interest in PA’s behavioral modeling, one of the famous structures is real-valued focused time-delay neural network, which is shown on Fig 2.

**2. Page 2**

\* In 2019, augmented real-valued time delay neural network based dpd was proposed which toke into account the envelope-dependent terms, fig 3 shows its basic structure. It is proved that solve the dc offset, I/Q imbalance and nonlinear PA distortion of a transmitter system by one step, see fig 4.

\* In the neural network structure, the adding envelope dependent terms make the proposed model generate richer basic function set, which further improve the modeling accuracy.

\* And the activation function usually is Sigmoid. Fig 5 shows the graph of the Sigmoid function.

**3. Page 3**

\* Fig. 6 indicates the structure of the proposed deep neural network of DPD, which is based on the ARVTD neural network structure. The proposed deep neural network adopts 9 hidden layers where each contains 10 neurons and delay tap (m) and nonlinear order (k) are set to 2 and 4, respectively.

\* What is more, to speed up the convergence of neural network and enhance its modeling accuracy, we utilize exponential linear unit (ELU) instead of Sigmoid/ReLU in this paper, which can avoid the gradient vanishing problem or ReLU inactive problem in corresponding cases.

\* Fig 7 shows three graphs of activation functions mentioned above and the mathematic expression of ELU.

**4. Page 4**

\* In the training process of back propagation neural networks, the derivative of activation is important for the convergence speed and accuracy of the modeling, especially in deep neural networks.

\* Sigmoid functions have small derivatives,especially in large input range. It will slow down the process of finding the optimal value for loss function like fig 9 and cause the gradient vanishing problem. ReLU has enough derivatives in positive input, but its derivatives equal to zero in negative input, which means some neurons will be inactive when there are many negative samples like fig 10.

\* These problems can be avoided by using ELU in deep neural network back-propagation process.[4][5]

**5. Page 5**

\* Fig 11 shows the SLCG PA in this experiment, and fig 12 indicates the modulated signal measurement results of the SLCG PA under 10MHz 64QAM signals.

\* SLCG PA is a recently developed back-off efficiency enhancement (BEE) technique that adopts two-quadrant modulation (TQM). The BEE technique brings new challenges for PA linearization.\* But it shows poor linearity and linearizability under wideband modulated signal excitations.

**6. Page 6**

\* Fig 13 shows the diagram of proposed dpd measurement test-bench, which adopts indirect learning structure.

\* In this measurement, the above SLCG PA was excited with 256QAM signals at the center frequency of 2.4 GHz with various modulation bandwidth varying from 20MHz to 200MHz, and further linearized using various DPD method at a Pavg of 30dBm with a DEavg of 38%.

\* The proposed DPD algorithm was implemented in Matlab to process the RF signals received by spectrum analyzer.

7. Page 7

\* Two figures above show the normalized Gain and Phase distortion with/without the proposed DPD, respectively. The SLCG PA shows intense nonlinearity and memory effect under the wideband signal excitations. However, when apply the proposed DPD technique, the intense distortion of normalized gain and phase has been mitigated substantially.

8. Page 8

\* In fig 17 and table 1, comparing existing DPD methods, the proposed offer a 4-8.4dB improvement in ACPR as well as about 1.3-4.3dB improvement in NMSE. Also by applying ELU function in deep neural network, the training process can be accelerated about 3-4 times compared with Sigmoid.

\* Fig. 18 illustrates the DPD results for the signal modulation bandwidth swept from 20MHz to 200MHz. The proposed DPD method can always realize effective linearization for the nonlinear PA excited with wideband modulated signals.

9. Page 9

\* Lastly, This paper proposes a deep ARVTDNN DPD technique, which employs ARVTD-based input vector and adopts ELU function to replace the sigmoid one in the neuron activation, and consequently avoids the gradient vanishing problem and accelerates the DNN training. Experimental verification conducted on an SLCG PA demonstrates that the proposed DPD maintains excellent linearization performance and enhanced stability in the case of large signal modulation bandwidth.