DESIGN AND TUNING OF DIGITAL POWER LINE CARRIER TO IMPROVE NETWORK LINE PARAMETERS AT HIGH VOLTAGE TRANSMISSION LINES

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Recepción: 30/07/2019 **Aceptación:** 20/09/2019 **Publicación:** 06/11/2019

Citación sugerida:
Khowaja, M.H., Halepoto, I.A. y Memon, S. (2019). Design and tuning of digital power line carrier to improve network line parameters at high voltage transmission lines. *3C Tecnología. Glosas de innovación aplicadas a la pyme. Edición Especial, Noviembre 2019*, 167-183. doi: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

Suggested citation:
Khowaja, M.H., Halepoto, I.A. & Memon, S. (2019). Design and tuning of digital power line carrier to improve network line parameters at high voltage transmission lines. *3C Tecnología. Glosas de innovación aplicadas a la pyme. Speciaal Issue, November 2019*, 167-183. doi: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

ABSTRACT

In this work, Digital Power Line Carrier (DPLC) over 3-phase 500kV/220kV high voltage transmission line is designed, configured, tuned and simulated using Micom software. The DPLC was configured for faster and efficient data transmission at longer distance in the range of 800km by reducing the noise using different enhanced digital techniques and advanced indoor/outdoor equipment. In this work, only YELLOW phase of 3-phase is used on the existing network of National Transmission and Dispatching Center, Pakistan while other phases can be used for transmission of data by reducing noise. The line matching units, coupling capacitors, wave traps and high frequency cables for the connection of DPLC to the HV line in grid yard were considered.

The Actual line condition measurent for attenuation and noise were carried out between two remote stations between 500kV Jamshoro and NKI Karachi. The line spectrum shows that in Rx (116 KHz to 124 KHz) band there is very high level of noise during the sweep time of 10sec, the initial condition of HV transmission line indicates the high noise of -3.951dB and analog line gain of 10.45 dB. To reduce this noise level, the DPLC was configured according to the line parameters.

After synchronizing the both DPLCs of 500kV Jamshoro and NKI Karachi, the initial line condition of HV line were measured again. The result confirms that line parameters (Noise, Attenuation and BER) are improved significantly. The results shows the in Rx band from 116kHZ to 124kHZ line spectrum, the noise level is decreased from -3.951dB to -13.471dB due to which the analog line gain was also improved from 10.45dB to 19dB. When DPLC was used for data transmission it confirms an excellent performance in terms of BER that is 99.6% error free during the 30minutes running time.

KEYWORDS

High voltage transmission lines, Digital Power Line Carrier, 500kV Jamshoro, NKI Karachi, Actual line Condition.

Edición Especial Special Issue Noviembre 2019
DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

1. INTRODUCTION

High voltage transmission lines (HVTL) are a considered as good means of transmitting information over different distance ranges. In most part of the world, power line carrier is used to transfer information via High voltage (HV) lines and has become an important instrument of the management and safety of electrical power systems (Arora, Thomas & Jain, 2019). The extremely high mechanical rigidity and high reliability of the interconnecting lines and terminal equipment under the control of power utility exhibits attenuation and moderate to long duration noise under normal atmospheric conditions. The HV lines exhibit attenuation in the carrier frequency range of 20 K Hz to 500 KHz (Acakpovi, Mohammed, Nwulu, Fifatin, Nounangnonhou, & Abubakar, 2019). Additionally the HV lines produce high short duration level (bursts) due to the operation of circuit breakers and load break isolators. Traditionally over HV lines, power line carrier (PLC) is widely used because it provides multiple channels for speech, data and teleprotection (Cortes, & Idiago, 2019). Previously analog power line carriers had been used to transfer information/data via HV lines but due to band width limitations, noise problems and low features in the analogue PLCs, the international recommendations for digital power line carrier (DPLC's) have come in to force. Additionally, the system may have the possibility of false signals or any kind of tripping in the presence of burst noise; the DPLC's can combat these problems. Through DPLC, 100 to 800km distance long range information can be transmitted without any use of repeater stations (Ndjiongue, & Ferreira, 2019).

Digital power line carrier is consisted of processing unit, amplifier unit and service unit configured in master/slave relationship offers comprehensive transmission capabilities over HV lines (Sagar, 2011). It supports voice/speech, data transmission and teleprotection with various commands to react to problems in the electrical network (Pavlidou, Vinck, Yazdani, & Honary, 2003). The DPLC has adaptive behavior and can also be used with SCADA system. The grid information/data can be taken from the RTU serial/parallel ports and then put to the DPLC for efficient transmission. The additional features can be achieved by using service unit and it is observed practically that the system does not produce perturbations or spurious noise within the band. DPLC can transmit data using particular frequency band from 4 kHz to 16 kHz wide within the range of 20 to 500khz. DPLC can be configured for wide range of parameters such as voice, data and protection of HV lines. Some parameters are set during the manufacturing stage and some are set during the installation and service start-up time.

2. MATERIALS AND METHODS

In this work, a DPLC based model is proposed for faster and efficient data transmission over high voltage transmission lines by reducing the noise. The proposed model is shown in Figure 1.

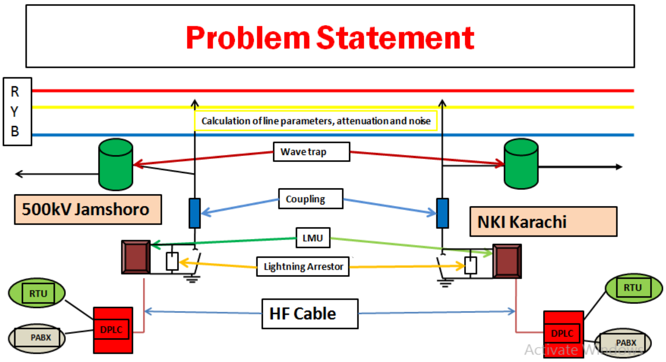

Figure 1. Proposed DPLC based model for data transmission.

In proposed model, a 3-phase HV transmission line from 500kV Jamshoro to NKI Karachi is considered with indoor and outdoor equipment arrangement. In this work, only single YELLOW phase is used on the existing network of National Transmission and Dispatching Center (NTDC), Pakistan while other one or two phases can be used for transmission of data by reducing noise. In the yard side, outdoor equipment contains the wave trap, coupling capacitor and line matching unit (LMU) with lightening arrestors which may protect the line equipment from heavy lightening strokes during the rainy season. The outdoor equipment is connected with the indoor equipment that is DPLC via HF (high frequency) cable of 75 Ω. The data from RTU and PABX relates to DPLC for transmission.

Edición Especial Special Issue Noviembre 2019
DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

2.1. DPLC CONFIGURATIONS

DPLC consists of mainly three parts; power amplifier, processing module and service module as shown in Figure 2.

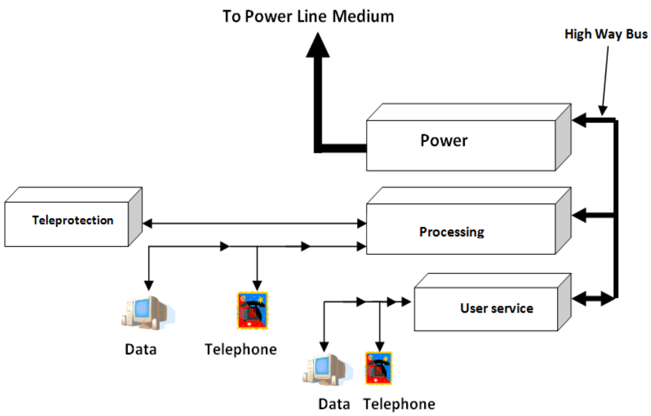

Figure 2. Digital power line carrier.

2.1.1. POWER AMPLIFIER

The DPLC offers programmable amplifier which is configurable with the Human-Machine Interface that can provide 40W power and it can be increased up to 80W for the long distance transmission HV line by adding a single AMPX unit Extension Amplifier (Waseer, Halepoto, & Joyo, 2014). The main boards that are used for power amplifier settings are amplifier (AMP), transmission filter board (TXF) and reception filter board (RXF). The AMP board is 40W class AB amplifier board (Halepoto, Kumar, Memon, & Ismaili, 2013). The TXF board is programmable 40W transmit filter, impedance matching; summing stage for 80W is always present. Filter setting is achieved with jumpers. Fine tuning is obtained by adjusting the inductance value of the 2 coils (screw adjusting) on the board. RXF is board programmable receive filter, it is only present on one of the two amplifier units. Fine-tuning is obtained by adjusting the inductance value of the three coils (screw adjusting). Jumpers on the TXF and on the RXF allow frequency settings: the pass-band can be 4 kHz, 8kHz, or 16 kHz wide, and is in the range 20kHz to 500kHz. After the setting of jumpers the fine tuning can be performed by using selective and feeding meters. After the completion of tuning process, the amplifier is configured, as shown in Figure 3.

Figure 3 shows the power amplifier configuration for 8 kHz frequency band. During the configuration process it is very important to select the QAM center frequency for Tx and Rx. The analog band of 4 kHz is selected for speech while other 4 kHz is selected for DATA transmission.

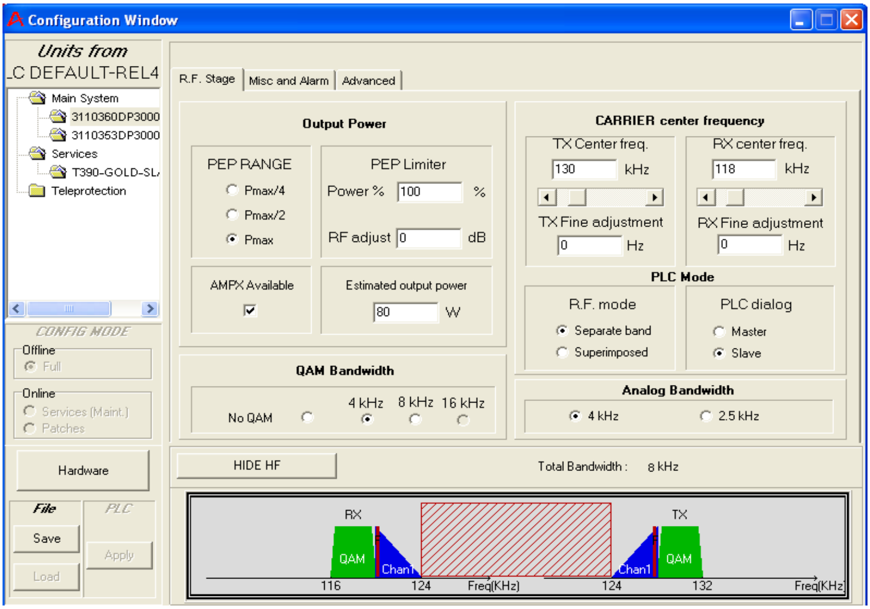

Figure 3. Amplifier Configuration.

2.1.2. PROCESSING UNIT

The processing unit (PRCS) is responsible to prepare the signals to be sent for the modulation, error detection and correction scheme. The PRCS digitally samples and modulates the signal using either QAM for normal data (to increase the data rates) or FSK for out-of-band data. The PRCS unit offers the high speed channel V11 can be configured by using a clock signal generated by processing unit on the master/ slave basis. The channel speed can also be set from the tool box of Micom software. The default value is 64kbps. The Signal to Noise Ratio (SNR) or Bit Error Ratio (BER), or both can be used as an exit and entry condition points at which the system

Edición Especial Special Issue Noviembre 2019
DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

switches into or out of fallback mode. The PRCS has different data ports, various combinations of DATA equipment (DTE or DCE) can be connected to DPLC. The data channel is configured as shown in Figure 4.

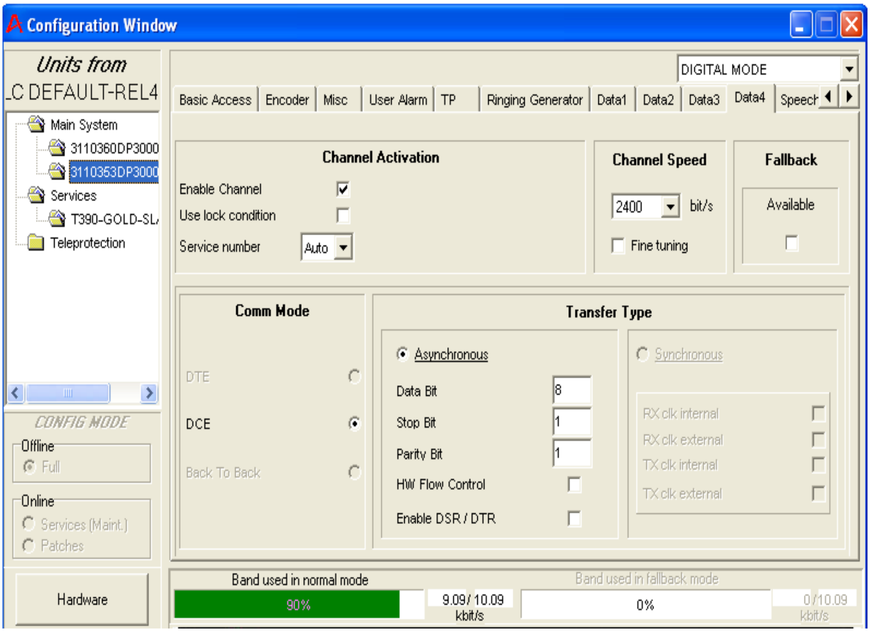

Figure 4. Processing Unit configuration for DATA.

In Figure 4, the PRCS is configured for data channel. Different data channels are available (DATA1, DATA2, DATA3 and DATA4) that can be used for transmission of data at various channel speeds. It is necessary to select the same speed at both stations. The data bits should be an integer from 1 to 9, whereas stop bit and parity bit 1 is used.

2.1.3. USER SERVICE UNIT

The services can be expanded by adding different service modules (maximum up to nine modules). The User Service Unit (USR) supports combinations of speech/ telegraph channels and data channels with up to six channels in total. Speech channels can be configured for both analog and digital modes in the service module. The input and output levels for analog speech is adjustable between -30db to +7db range. The level setting should be identical at both end stations. This is set in accordance with the capabilities of the PABX line to which the channel is connected.2W/4W/ defines how many wires are to be used for the channel on the PABX. The options are two (the default), four, or automatic detection from the PABX using W-Wire. To reduce the noise for improving the quality of speech several combinations of equipment such as PABX, phone and fax can be connected to the DPLC. The configuration for speech is set as shown in Figure 5.

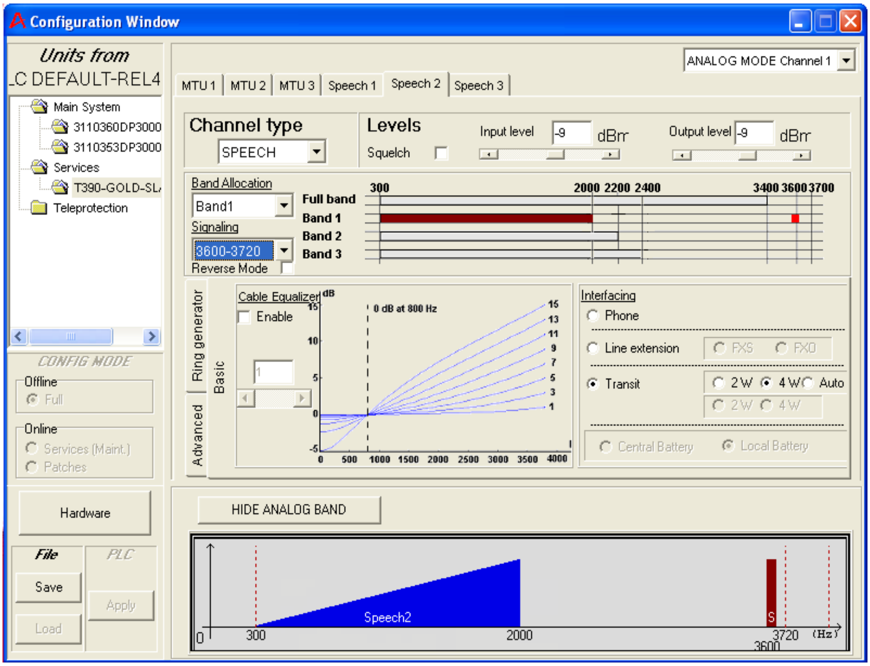

Figure 5. User Service Unit configuration for speech.

In Figure 5, the speech channel is configured by setting the input and output dB levels by keeping the measured noise levels of the HV line. The burst noise and atmospheric noise both are the main factors which affect the quality of speech. In this work the capacitive coupling and band rejection filters are used to reduce the noise level for the improvement of speech.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

3. RESULTS

3.1. TRANSMISSION LINE AND NETWORK CHARACTERISTIC PARAMETERS

In HV lines, 3-phase transmission is preferred due to minimum system losses by using different methods for the transmission of speech and data. In this work, the various characteristics of HV line are taken into consideration.

3.1.1. NOISE IN HV LINE

Noise is the random fluctuations in an electrical signal, which generates an error or undesired random disturbance in information signal. Noise is the major problem in HVTL due to which the interruptions occur in the data dissemination from one station to the next station. The HV lines can be affected by various types of noise including burst noise, atmospheric (Static) noise, solar noise and etc. According to the typical noise levels of 3-phase HVTL are given in Table 1.

Table 1. Noise levels of 3-phase HVTL.

Power line voltage (kV)	frequency KHz	48-100	150	200	250	300	350	400	450
34.5-161	Fair weather	-38 to -43	-39 to -44	-40 to-45	-41 to -46	-42 to -47	-43 to -48	-44 to -49	-45 to -50
	Adverse weather	-21to -26	-22 to -27	-23 to -28	-24 to -29	-25 to -30	-26 to -31	-27 to -32	-28 to -33
230-345	Fair weather	-33 to -38	-34 to -39	-35 to -40	-36 to -41	-37 to -42	-38 to -43	-39 to -44	-40 to -45
	Adverse weather	-16 to -21	-17 to -22	-18 to -23	-19 to -24	-20 to -25	-21to -25	-22 to -26	-23 to -26
500	Fair weather	-31to -36	-32 to -37	-33 to -38	-34 to -39	-35 to -40	-36 to -41	-37 to -42	-38 to -43
	Adverse weather	-11to -16	-12 to -17	-13 to -18	-14 to -19	-15 to -20	-16 to -21	-17 to -22	-18 to -23

3.1.2. LINE NOISE OF 500KV HV LINE

In this work, two stations have been selected for the measurement of noise levels by using selective meter ALT-2000 500kv Jamshoro and 500kv NKI, Karachi. The Table 2 shows the calculated values of noise.

Table 2. Line Noise of 500kv HV line.

S/No.	Frequency (KHz) Impedance: 75 Ω Level: 0 dBm LMU: 48-136KHZ	Line Noise at 500kV Jamshoro	Line Noise at NKI Karachi
		ALT 2000 Settings, RF Response at 75 Ω	ALT 2000 Settings, RF Response at 75 Ω
1	50	-10.6	-12.6
2	60	-10.5	-12.7
3	70	-11.2	-11.4
4	80	-12.0	-13.2
5	90	-12.1	-13.7
6	100	-13.2	-14.8
7	110	-13.9	-14.9
8	120	-13.8	-15.1
9	130	-13.1	-15.2
10	140	-13.7	-15.5

3.2.1. LINE ATTENUATION

Attenuation is the loss in the transmitted signal due to line impedance and power cable impedance. In HV lines, attenuation weakens the signal strength. The maximum allowable attenuation is dependent on the DPLC receivers used at transmission line terminals. Mathematically it can be calculated as follows:

Where,

Z1 is Power Cable impedance (75Ω), Z2 is line impedance (300Ω).

3.2.2. LINE ATTENUATION OF 500KV HV LINE

The line attenuation between 500kV Jamshoro and 500kV NKI, Karachi is carried out by using ALT-2000 meter. The Table 3 showing the results of line attenuation.

Table 3. Line Attenuation of 500kV HV line.

S/No.	Frequency (KHz) Impedance: 75 Ω Level: 0 dBm LMU: 48-136kHz	Line Attenuation 500kV Jamshoro	Line Attenuation NKI Karachi
		ALT 2000 Settings RF Response at 75 Ω	ALT 2000 Settings RF Response at 75 Ω
1	50	15.5	16.0

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S/No.	Frequency (KHz) Impedance: 75 Ω Level: 0 dBm LMU: 48-136kHz	Line Attenuation 500kV Jamshoro	Line Attenuation NKI Karachi
		ALT 2000 Settings RF Response at 75 Ω	ALT 2000 Settings RF Response at 75 Ω
2	60	17.3	18.2
3	70	19.6	19.0
4	80	21.4	22.4
5	90	22.8	22.0
6	100	23.5	23.0
7	110	23.9	24.0
8	120	24.1	23.0
9	130	25.3	25.0
10	140	26.2	25.5

3.3. MEASUREMENT OF INITIAL LINE CONDITION

After synchronising the both DPLCs of 500kV Jamshoro and NKI respectively, different characteristics of the network were being viewed and studied for the transmission of data over the line, but it was found that the initial condition of HV line is very noisy as shown in the Figure 6.

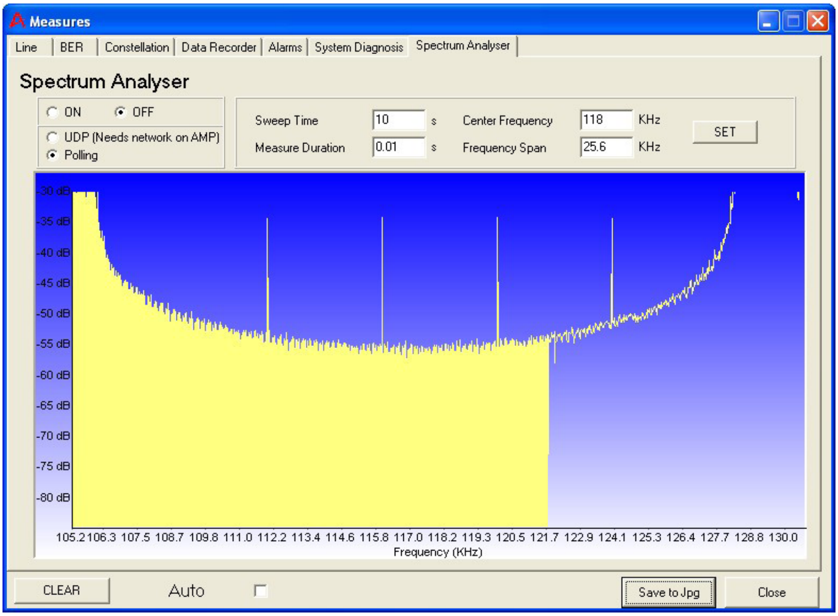

Figure 6. Initial condition of HV line.

The Figure 6 illustrates the initial line condition with high level of noise; the line spectrum shows that in Rx (116 KHz to 124 KHz) band there is very high level of noise during the sweep time of 10sec. When DPLC related to the active line at 500kV Jamshoro in direction to NKI Karachi, the Active HV line results are shown in Figure 7.

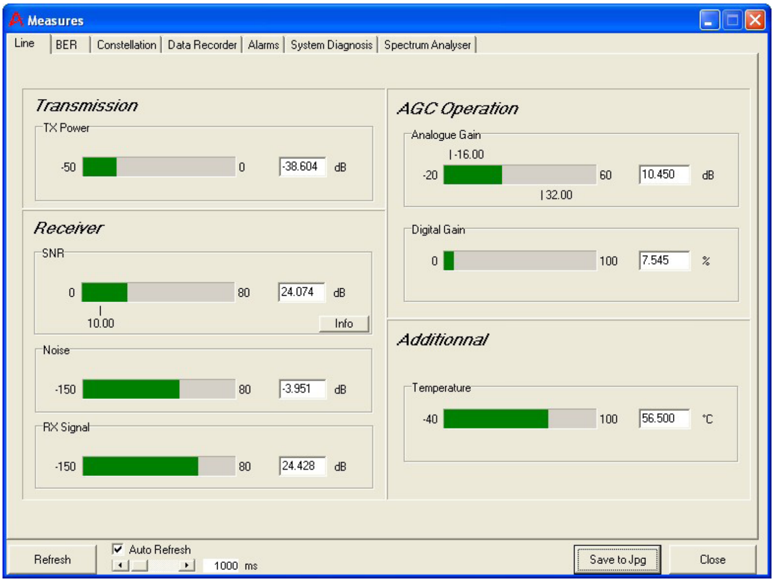

Figure 7. Active HV line results.

Figure 7 shows the initial condition of HV transmission line which indicates the high noise of -3.951dB and analog line gain is 10.45 dB. There are certain effects of atmospheric conditions on the HV line, as in Figure 7 the temperature is approximately 56.5Ċ due to which the noise increases in the line. In order to get the desired results DPLC will be configured by setting its parameters.

4. DISCUSSION AND/OR CONCLUSIONS

During the experimental work and measurements, it was concluded that there are certain noise problems in the HV line between from Jamshoro to Karachi. Thus, DPLC was designed and configured to take the initial condition line spectrum.

Edición Especial Special Issue Noviembre 2019
DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183

4.1. TUNING AND CONFIGURATION OF DPLC FOR INITIAL LINE CONDITION

To reduce the initial line condition noise, DPLC was tuned as shown in Figure 8.

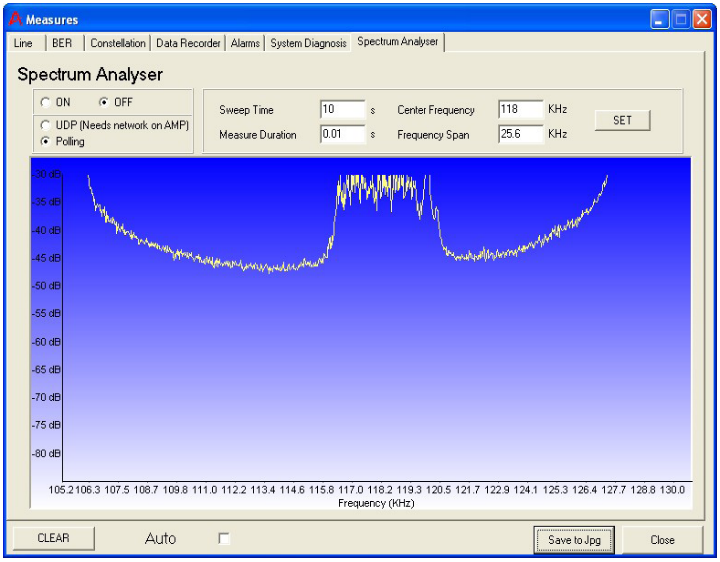

Figure 8. Low noise in Rx band after DPLC tuning.

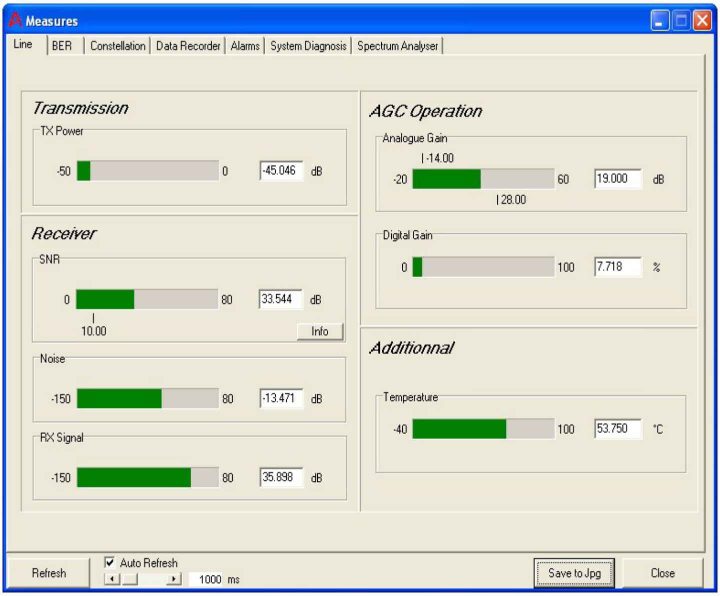

Figure 9. Reduced Noise Measurement Window.

From Figure 8, it can be observed that in Rx band from 116kHZ to 124kHZ the spectrum is much better as compared to Figure 6. The noise measurement window is shown in Figure 9, where the noise level is decreased from -3.951dB to -13.4dB due to which the AGC is also improved. On this line, the data transmission can be observed in terms of BER as shown in Figure 10.

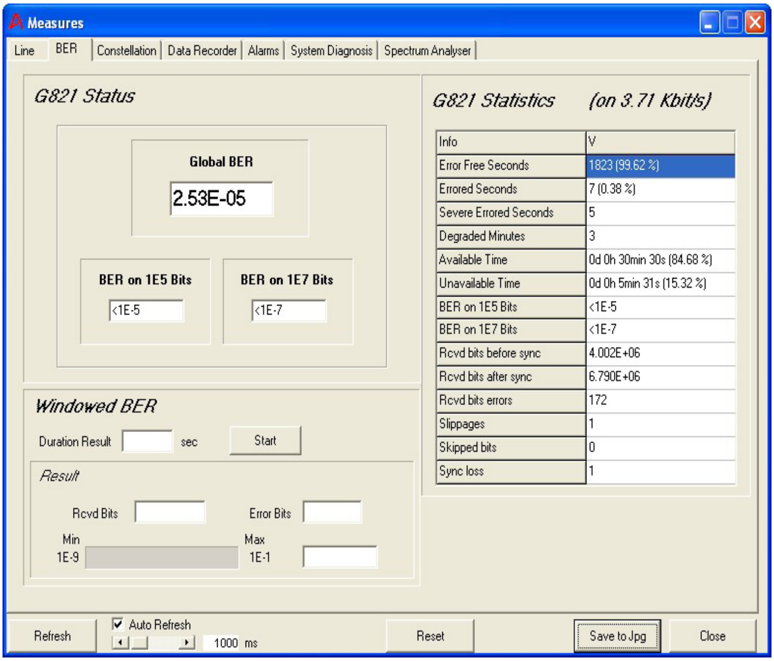

Figure 10. Improved BER.

When DPLC was used for data transmission as shown Figure 10, it confirms an excellent performance in terms of BER that is 99.6% error free during the 30min running time.

5. ACKNOWLEDGMENTS

Authors are highly grateful to Mehran University of Engineering and Technology, Jamshoro, Pakistan, for the necessary support, technical laboratory facilities and comfortable research environment.

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Edición Especial Special Issue Noviembre 2019
DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue3.167-183