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A Methodology on Physical Measurements for Subscriber's Digital Network Qualification

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Abstract: *This work presents a methodology for the measurement of the main physical parameters of the subscriber digital link. For this methodology, some important procedures are indicated, such as: adequate selection of the equipment/devices for the measurements, adequate choice of the calibration process for the measurements and the accomplishment of a statistical treatment of the measured parameters: input impedance, transfer function and scatter parameter. The validation of the methodology was performed through some case studies considering two situations: one, when all the measurement procedures were performed according to the methodology and another, when the measurements did not follow the proposed procedures. In both cases cited above, the methodology proved to be quite effective and presented coherent measurements, within reliable values.*

Keywords: *DSL. Link Qualification. Measurement Methodology.*

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I. Introduction

There is currently significant growth in access to broadband services. This is due in large part to the proliferation of the use of DSL (Digital Subscriber Line) technology, which, using an already available infrastructure (telephone network of copper wire pairs), allows, mainly to the home user, access to a range of services such as: Internet, Voice over IP (Internet Protocol) and Video on Demand [1]. However, the use of the telephone network for this type of traffic imposes on operators new requirements and procedures for quality, operation and maintenance of the communication medium [3].

In the case of DSL access technology, one of these new procedures that assist the operators, both in the installation process and in the maintenance of this access technology, is the so-called Subscriber Link Qualification. Through the Qualification of the Link, it is possible to estimate the operational state of the subscriber line in providing access to services with the necessary quality.

The subscriber's digital link qualification can be performed using two techniques: Single Ended Line Testing (SELT), which allows the estimation of the transmission conditions of the subscriber's link without the need to move a specialized technician to the subscriber's home, and Dual Ended Line Testing (DELT), whose difference from the previous one is due to the existence of specific or technical equipment to perform the tests on the subscriber side [4].

In this context, the objective of this work is the elaboration of a methodology for measuring the parameters Z_{in} Input Impedance, S_{11} Scattering Parameter and H(f) Transfer Function, which are necessary to obtain an operational diagnosis of the link. For this methodology, criteria and procedures must be followed to obtain reliable and consistent data/measurements. These criteria involve the correct selection/ specification of the measurement setup devices, in view of their electrical characteristics; the performance of appropriate calibration procedures, a measurement sensitivity analysis and a post-processing phase of the data, which involves the statistical treatment of data for the purpose of observing data consistency.

II. Basic Parameters

2.1 The Copper Link

Through these 100 years of evolution of the telephone network, one factor has remained constant: telephone is still connected to the network by a twisted pair of copper wires. The reason for this is simple economics: attempts to replace it with more modern technology cost more than the revenue form basic phone bill could support. Copper wire is relatively inexpensive, it is in place, and it does the job [3].Age and quality of the cable also have a great deal to do with how much noise is present. If we are reused the existing twisted pair local link for high speed service distribution, then we have to deal with line attenuation (cable loss) which increases with line length and frequency and decreases as wire diameter increases [3].A link is divided into two parts: the feeder and the distribution segments. Feeder cables are large, high pair count cables that leave the CO and head down major corridors. Periodically, a certain number of pairs are dropped to a distribution frame and connected to distribution cables, which actually deliver service to the subscriber (see Figure. 1) [1].

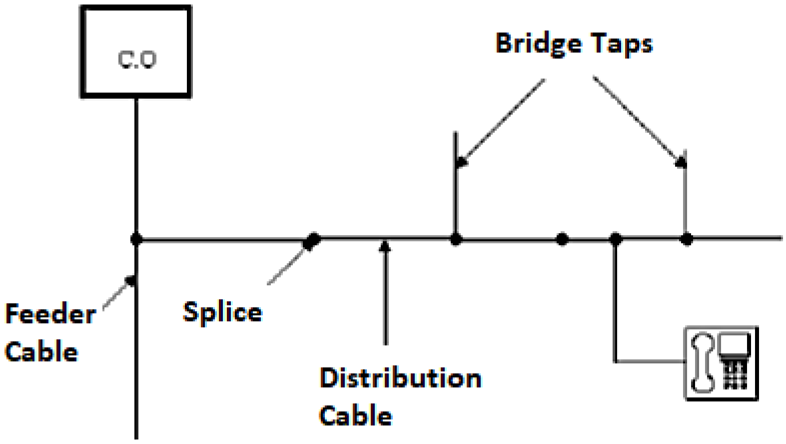

Figure 1: Typical copper feeder/distribution link [1].

2.2 Characteristic Impedance

This subsection is a review of the relationships between the characteristic impedance, propagation constant and the primary parameters R, L, G and C. Characteristic impedance is associated to with propagation constant and it is readily viewed as being complex, consisting of the real attenuation and imaginary phase coefficient components. The two secondary components are related to the primary components. Frequency dependence of these parameters is also developed.

Complex characteristic impedance Zc and the propagation constant γ are related with the primary parameters by [4]:

$$Zc = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \qquad (1)$$

Relationship between propagation constant and the primary parameters by [4]:

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \qquad (2)$$

by separating (2) in its real and imaginary parts, we can obtain the attenuation coefficient α and phase coefficient β respectively. These two parameters are defined according to [4] as:

$$\alpha = \sqrt{-\frac{1}{2}\left(\omega^2 LC - RG\right) + \frac{1}{2}\sqrt{\left(R^2 + \omega^2 L^2\right)\left(G^2 + \omega^2 C^2\right)}} \qquad (3)$$

$$\beta = \sqrt{\frac{1}{2}\left(\omega^2 LC - RG\right) + \frac{1}{2}\sqrt{\left(R^2 + \omega^2 L^2\right)\left(G^2 + \omega^2 C^2\right)}} \qquad (4)$$

where:
R is the resistance of the twisted-pair (Ohms/meters);
L is the inductance of the twisted-pair (Henry/meters);
C is the capacitance of the twisted-pair (Faraday/meters);
G is the conductance of the twisted-pair (Siemens/meters);
ω is the radian frequency (rad/s).

Characteristic impedance of a cable can be obtained by:

$$Z_0 = \sqrt{Z_{SC} \times Z_{OC}} \tag{5}$$

where:

– Input impedance of a link terminated by a short-circuit (ZSC);
– Input impedance of a link terminated by an open-circuit (ZOC).

Whenever there is a mismatch between the link and the load, reflections will occur. When a link is terminated by an open end, the reflection coefficient at the load is $\Gamma = 1$ which means the reflected wave has the same amplitude and is in phase with the wave from the source. When a link is terminated by a short circuit, the reflection coefficient at the load is $\Gamma = -1$, which means the reflected wave has the same amplitude but is out of phase with the wave from the source. As the reflections in these two cases differ from 180^{o}, their influence will cease if these impedances are multiplied with each other, since:

$$Z_{OC} \times Z_{SC} \Rightarrow \angle Z_{OC} + \angle Z_{SC} \tag{6}$$

Although (5) represents the characteristic impedance, this expression does not give us the effects of reflections.

2.3 The Twisted-Pair Cable as a two-port Network

Every twisted-pair cable can be accurately modeled as a two-port network (2PN). In transmission line theory, a common way to represent a 2PN is to use the transmission matrix, also known as the ABCD matrix [5]. Figure 2 shows a model of a telephone subscriber link [5].

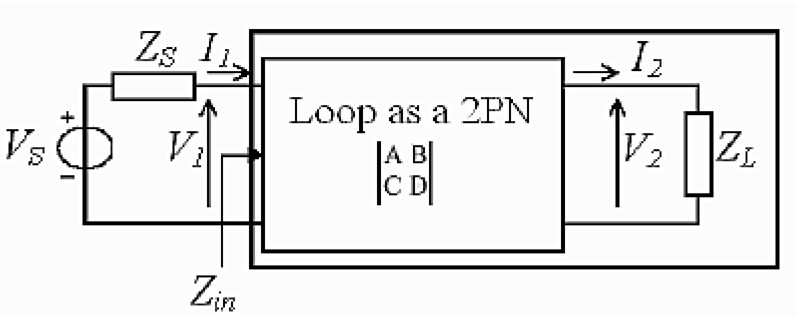

Figure 2: 2PN (Two-Port Network) representation of the subscriber loop [5]

2.3.1 Input Impedance

Input impedance of a subscriber link is defined as the ratio between the voltages applied to the input of such circuit and its resulting current [1]. The relationships between the input and output variables of the two-port network are:

$$V_1 = AV_2 + BI_2 \tag{7}$$

$$I_1 = CV_2 + DI_2 \tag{8}$$

According to Figure 2, it is possible to notice that $V_2 = Z_L I_2$. Thus, the ratio between the current and the voltage over the load can be expressed by

$$\frac{I_2}{V_2} = \frac{1}{Z_L} \tag{9}$$

$$\frac{V_1}{I_1} = \frac{AV_2 + BI_2}{CV_2 + DI_2} \tag{10}$$

Dividing (7) by (8) we have

Thus, assuming Zin =$I_1/V_1$and applying (9) in (10), we obtain

$$Z_{in} = \frac{AZ_L + B}{CZ_L + D} \quad (11)$$

2.3.2 Transfer Function

In a general way, the transfer function of a system can be defined as a mathematical statement that describes its transfer characteristics, i.e., the relationship between the input and the output of a system in terms of the transfer characteristics. Transfer function is a frequency dependent quantity and it rolls off with frequency. This is a consequence of the greater interaction between the propagating signals and the material comprising the transmission medium. For a perfectly terminated link with length *l*, the transfer function is given by $H(l,f) = e^{-l\gamma(f)}$, where γ is the propagation constant of the link. However, such a simplified twisted-pair cable transfer function based on the propagation constant is only good for a single gauge twisted-pair with perfect terminations at both ends. A subscriber link, however, usually consists of many sections of different gauges, with bridged taps, and terminated with resistive impedance [1], [5].

Transfer function of a telephone subscriber link is not a simple product of transfer functions of these twisted-pair cable sections because of impedance mismatches. To accurately represent a subscriber link channel, the concept of a two-port network and its ABCD parameter representation is normally used for the analysis of DSL systems.

Transfer Function is an important parameter used for defining the maximum allowable cable length and the frequency response of the cable. The attenuation is defined as the forward transmission S-parameter called S21. According to Figure 2, it is possible to notice that [1]:

$$\frac{V_1}{V_S} = \frac{AZ_L + B}{AZ_L + B + CZ_L Z_S + DZ_S} \quad (12)$$

Finally, we have

$$\frac{V_2}{V_S} = H_f(f) = \frac{Z_L}{AZ_L + B + CZ_L Z_S + DZ_S} \quad (13)$$

2.3.3 Scattering Parameter S11

S-Parameters are relatively easy to obtain at high frequencies. These parameters relate the most common measurements (gain, loss, reflection and transmission coefficient …). We can compute H, Y or Z parameters from S-parameters if desired [6]. In this paper, the one-port scattering parameter S11, which is ratio of the reflected wave and the incidente wave, is measured by means of a network analyzer (NA) directly in the frequency-domain. As only the CO end of the network may be considered as a one-port. All the information that can be acquired about the network through port 1 is contained in the S11 scattering parameter.

III. Related Work

Given the problems in the DSL services offer, many developed to improve the quality of the subscriber's link. However,

new methodologies that help in solving these problems are still being sought. In this section some of these works will be described.

The work [10] suggests the application of a model called VBU0 to estimate the the transfer function of the link, from the measurements of the line parameters. This model is validated with measures and simulations for some network topologies, considering a case of a simple network, with a bridged tap or a cascade network with two sections.

For each situation described above, it was found, from the primary parameters and a mathematical model for the S11 spreading parameters and for the of transfer H (f). Through this model, it is possible to obtain information about the topology of network, which is initially considered unknown.

In [11], the problem of link qualification using SELT is performed through of conventional TDR techniques, from the limitations of the nature of the subscriber line. In this work an algorithm is analyzed, considering the statistical knowledge of the link. The main relation through the proposed algorithm is the deterministic exploration of the use twisted pair models. Afterwards, the models were validated through experiments. Simulations were also carried out to compare the results obtained with the help of TDR to choose the topology that is closest to a true situation. To validate the Simulation results were obtained through computational techniques and the results compared to the measures obtained through TDR. These simulations and measures take into different situations concerning the change of gauge of the cable.

As in [11], reference [12] uses a mathematical model of the subscriber, from the input impedance parameters and the different cables (gauges) to estimate the length of the link through the use of TDR. O model uses different network topologies (with or without bridged tap) to validate your result. These results are compared with the information the operators.

In [13], a specialist system for local link identification and classification was developed through the use of TDR. The objective of this system was to estimate the between the central and the subscriber, based on the TDR and spectral power density of the noise from the central. These measures are processed using advanced techniques of digital signal processing, artificial intelligence and identification of systems to estimate the transfer function, in which estimate the capacity of the channel. The system still uses the network-based VBU0 model of two lines.

In the work [14] a technique is proposed to evaluate the accuracy of the loop make-up identification and identification of the link, without any prior knowledge the topology of the link. This technique uses a method by analyzing TDR to evaluate and identify a single ended loop make-up. The method consists of estimating the channel transfer function; for this, an algorithm was developed that, through the extraction of the obtained TDR signal, is able to estimate a certain topology of the network. That estimation is made from the reflected signal, ie the difference between the measured TDR signal and the simulated TDR signal. In the second part of reference [15] an extension of the work is made to from an evaluation of the performance of such algorithm through TDR techniques extended models [11], which use impulse response models and ML algorithms (Maximum Likelihood). Another contribution of this work is a implementation of a multiple topologies estimation through the Bellcore's measurements from 1987-1990.

IV. Measurement Methodology

The methodology proposed in this article consists of two steps, as shown in the diagram in Figure 3. The first step consists of the measurements of the physical parameters of the chosen link. The second is to analyze the results of the measurements obtained, through a statistical analysis.

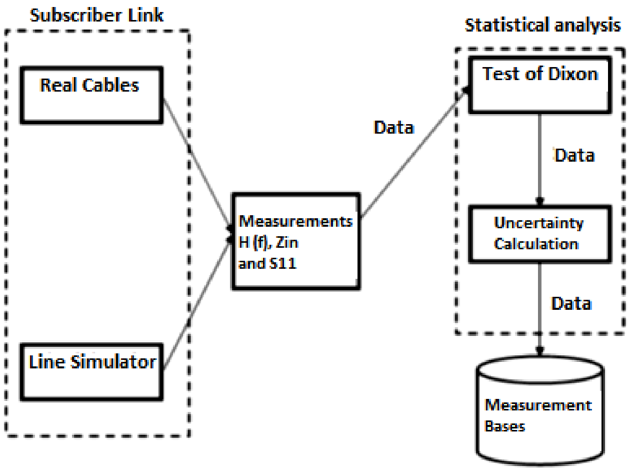

Figure 3: Implementation Diagram of the Methodology [2].

4.1 Measurement Setups

This section shows the current setups used for the measurements of the parameters shown in Figure 3, assuming that the DUT can be a real cable or a line simulator [2].

4.1.1 Setup for Input Impedance Measurement

To perform the input impedance measurement, the equipment required for the setup is shown in Figure 4. The 4294A precision impedance analyzer is connected to the unbalanced port of the BALUN 0301BB via the 16047E fixed test. The DUT connects to the balanced port of the BALUN using an appropriate cable and an RJ45 or RJ11 connector. The 82357B USB/GPIB interface connects to the impedance analyzer through a parallel port and to the computer using the GPIB port.

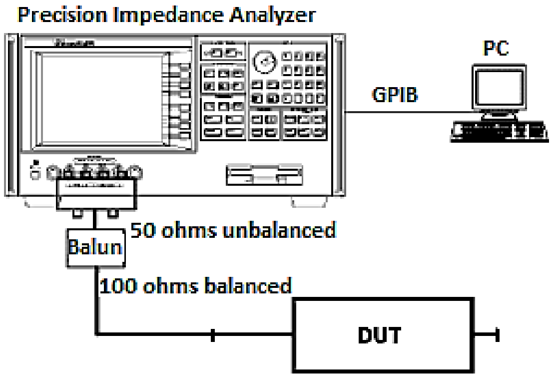

Figure 4: Setup for Input Impedance Measurement [7].

4.1.2 Setup for Transfer Function Measurement.

To perform the transfer function measurements the setup used is shown in Figure 5. In this setup, the 4395A network analyzer connects to the first BALUN through the test set 87512A using the reference input port (R), the reference output (RFout) and the transmission input port (A).The second BALUN connects to the reflection output port (B) via a male BNC/BNC cable. On the balanced ports of the BALUNS, the DUT is connected through two appropriate cables with RJ45 or RJ11 connectors. The 82357B USB/GPIB interface connects to the network analyzer through a parallel port and to the computer using the GPIB port.

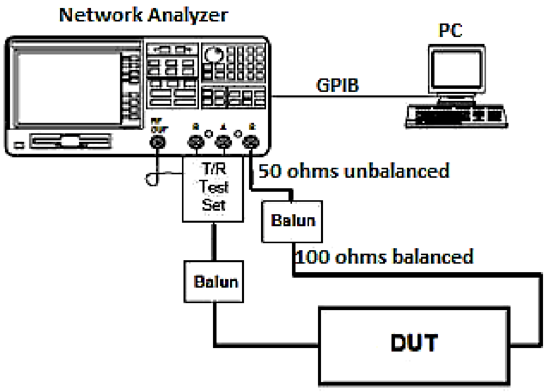

Figure 5: Setup to measure the Transfer Function [5].

4.1.3 Setup for S11 Scatter Parameter Measurement

To perform the S11 scatter parameter measurement, the equipment required for the setup is shown in Figure 6. In this setup, the 4395A network analyzer connects only through a BALUN 0301BB to the 87512A test set, using the input port of reference port (R), the reference out port (RF out) and the transmission inlet port (A). In the balanced port of the BALUN, the DUT is connected through an appropriate cable with RJ45 or RJ11 connector. The 82357B USB/GPIB interface connects to the network analyzer through a parallel port and to the computer using the GPIB port.

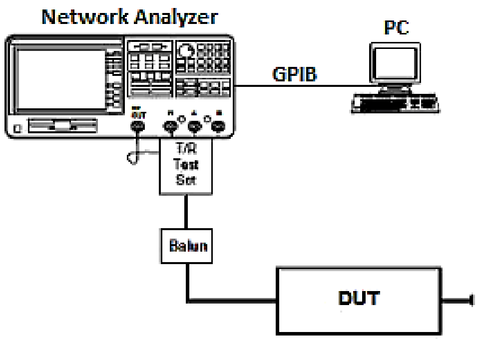

Figure 6: Setup for measuring S11 Scattering Parameter [7].

4.2 The Calibration Process

The measurements of the parameters of the subscriber's link are made by devices that are subject to errors. To remove these systematic errors some calibration techniques have been developed, such as: SOLT (short-open-load-thru), TRL (thru-reflection-line) and LRM (line-reflection-match) [6]. These techniques have advantages and disadvantages. So a careful choice is recommended to find the most appropriate calibration procedure for each specific application. All these techniques include some variation, the three techniques being used mainly for analysis of the S-scattering parameters. S-parameter measurements are based on the ratio of reflected and incident waves through the characteristic impedance of the system [6]. Between the signal source and the device port, many components are found, such as: connectors, adapters, baluns, cables, and so on. These system components represent possible losses and discontinuities. As a result, a calibration procedure is necessary to remove the errors produced by component imperfections.

4.3 Statistical Treatment of DSL Measurements

Most of the measurements used in this work, however optimized their performance capacity, are not exempt from causing errors when they are used. Therefore, a statistical treatment of the values of the measured physical parameters of the subscriber link was necessary, with the intention to identify the errors of a systematic and/or random nature committed in the measurement processes. In this sense, some procedures were adopted to perform the statistical treatment. These procedures are described in the following sections.

4.3.1 Application of the Dixon Test

There are many tests to identify outliers (discrepant value or atypical value). The four common outliers for normal distribution are: the Rosner test, the Dixon test, the Grubbs test, and the Cochran test. These techniques are based on hypothesis testing, especially regression methods [2].

In this work the Dixon test was used, due to its good accuracy and speed in the detection of outliers values. The choice of this test was due to its ease and because it is a simple and effective method. In addition, the determining factor in your choice is: the possibility of the test being applied in a considerable amount of samples. Another advantage is that a priori knowledge of the estimation of these values is not necessary.

4.3.1.1 Test of Dixon

This test aims to identify values that are far from the sample. It has the advantage that it is not necessary to know the estimate of the standard deviation [2]. To perform the test, the following steps are performed:

1 - Sort the values in ascending order, that is: x1 <x2 <x3 <.... <xn-1 <xn

2 - Consider the hypothesis that the smallest value x1, or the largest value xn, is a suspect as an outlier value.

3 - Select the desired risk of false rejection.

4 - Apply the following equations, according to the sample size as shown in Table 1.

Table 1: Dixon test.

n	If xn is suspect	If x1 is suspect
$3 \leq n \leq 7$	$(x_n - x_{n-1}) / (x_n - x_1)$	$(x_2 - x_1) / (x_n - x_1)$
$8 \leq n \leq 10$	$(x_n - x_{n-1}) / (x_n - x_2)$	$(x_n - x_1) / (x_{n-1} - x_1)$
$11 \leq n \leq 13$	$(x_n - x_{n-2}) / (x_n - x_2)$	$(x_3 - x_1) / (x_{n-1} - x_1)$
$14 \leq n \leq 25$	$(x_n - x_{n-2}) / (x_n - x_3)$	$(x_3 - x_1) / (x_{n-2} - x_1)$

5 - Compare the ratios calculated with the critical values - Dixon test. If the value found is greater, then the assumption of Outliers exists.

4.3.1.2 Procedures for Conducting the Dixon Test

After collecting the measurements, the data is stored in .xls format files, each file being composed of three columns that are: frequency, real part and imaginary part for every frequency band used. For each value of the real and imaginary part the Dixon test is used. After processing, an output file is generated in the .txt format for analysis of the results. Considering that the number of outliers found is less than 15% of the total sample, these data can be stored for use in the next step. Otherwise, this data is discarded and new measurements are taken.

4.4 Application of Uncertainty in Measurements

In this step, the associated uncertainty in the measurements is determined by using the standard deviation of the n measurements made. The confidence interval used to estimate the measurement uncertainty was 95.44% [8].

V. Results and discussion

ETSI standards (#1, #2, #3, #4, #5, #6, #7 and #8) were used to perform the measurements as described in Table 2. The measurement campaign was performed in two steps. For the first, transfer function measurements, S11 spreading parameter and input impedance were made, initially using the line simulators. In the second stage of the measurement campaign, measurements of the parameters mentioned above were made using a real link, composed of a section of telephone cable as described in Table 2. The objective of this step is to prove that the methodology can be applied to the actual links found in the current telephone networks.

Table 2: Description of the Scenarios Used in the Implementation of the Methodology

Link	Number of Sections	Section Type	Section Length (m)	Diameter of section gauge (mm)
ETSI#1	1	Serial	2.550	0,4
ETSI#2	1	Serial	3.400	0,5
ETSI#3	2	Serial/Serial	1.400/1.500	0,4/0,5
ETSI#4	4	Serial/Serial/Serial/Serial	200/900/1.500/500	0,32/0,4/0,5/0,63
ETSI#5	4	Serial/Serial/Serial/Serial	1.450/750/500/500	0,4/0,5/0,63/0,9
ETSI#6	3	Serial/Serial/Serial	1.300/1.250/500	0,4/0,5/0,63
ETSI#7	3	Serial/Serial/Serial	200/600/4.000	0,32/0,4/0,9
ETSI#8	4	Serial/B.Tap/Serial/B. Tap	750/500/1.100/500	0,4/0,4/0,4/0,4
Cabo Real	1	Serial	500	0,4

B.Tap = *Bridged Tap*

The results for the transfer function H(f) determined with the application of the methodology are shown in the following figures. The graphs of Figures 7 and 8 show the results of measurements of the transfer function H(f) for the standard ETSI #1 and ETSI #8 linkages using line simulator.

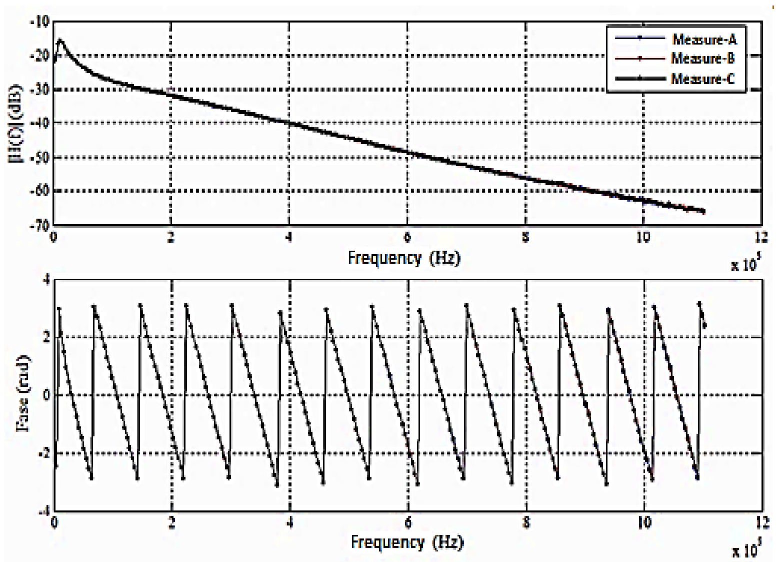

Figure 7: ETSI # 1 - Magnitude and Phase for H(f).

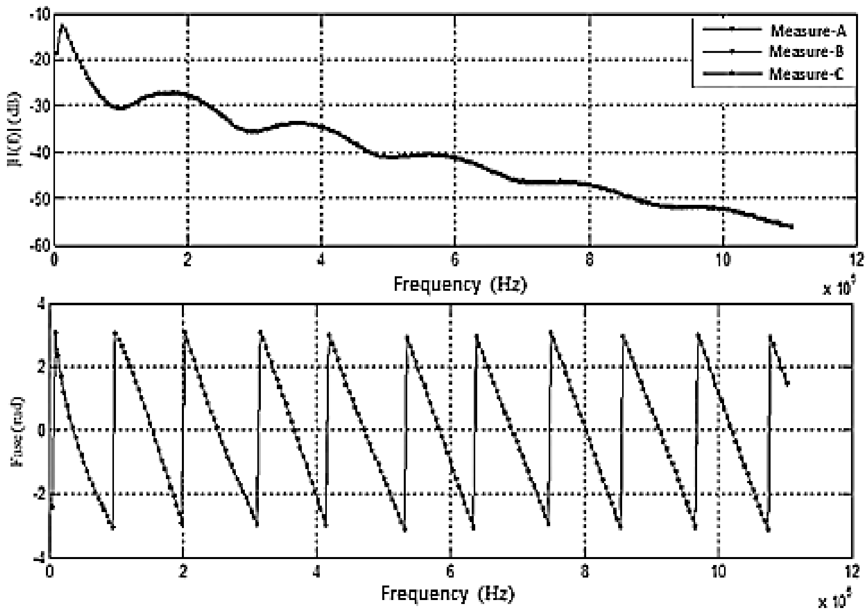

Figure 8: ETSI # 8 - Magnitude and Phase for H(f).

The results for the S11 spreading parameter determined with the application of the methodology are shown in the following figures. The graphs of Figures 9 and 10 show the results of the S11 spreading parameter measurements for the standard ETSI #1 and ETSI #7 linkages using line simulator.

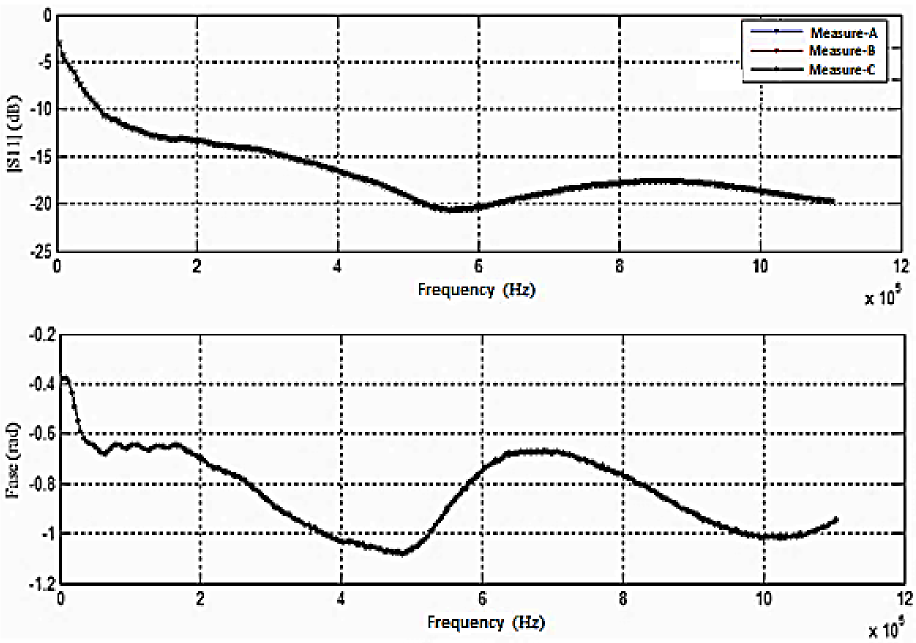

Figure 9: ETSI # 1 - Magnitude and Phase for S11

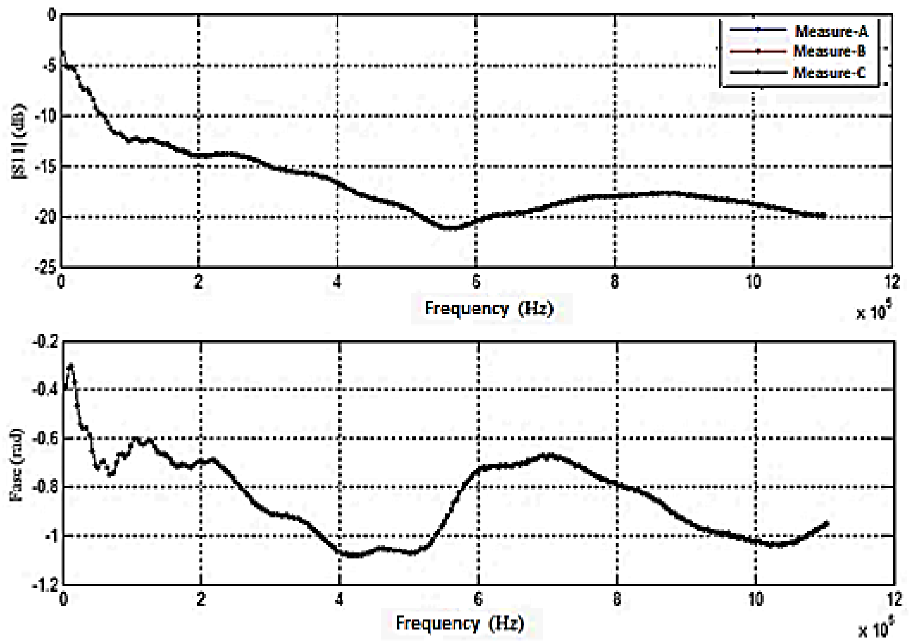

Figure 10: ETSI # 7 - Magnitude and Phase for S11.

The results for the Zin input impedance determined with the application of the methodology are shown in the figures that follow. The graphs of Figures 11 and 12 show the results of the input impedance measurements for standard ETSI # 1 and ETSI # 8 linkers using line simulator.

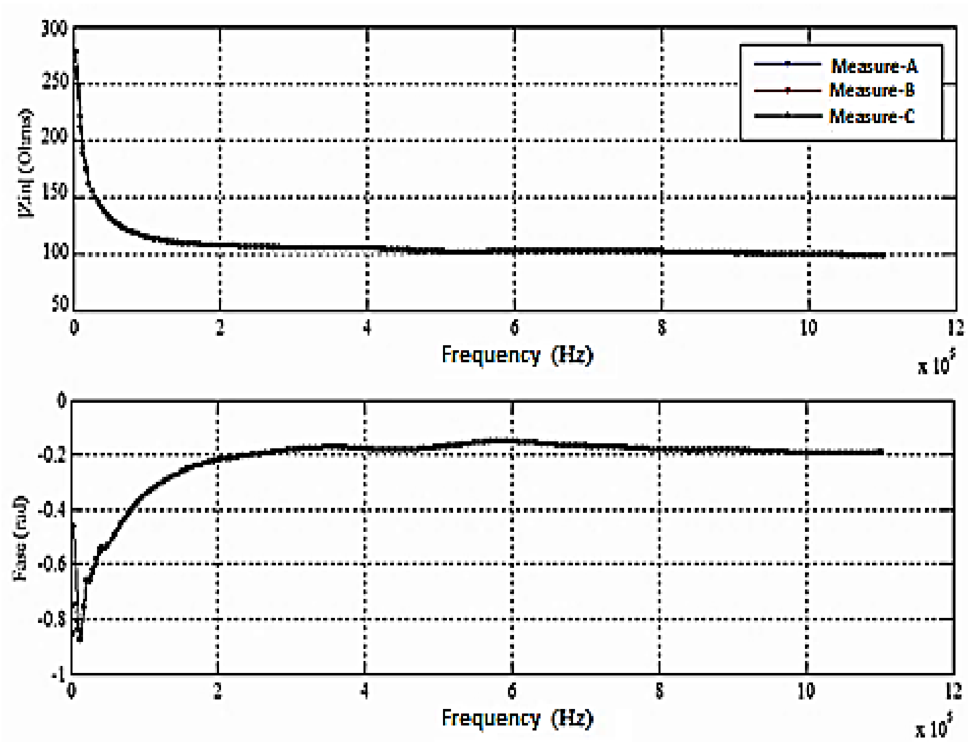

Figure 11: ETSI # 1 - Magnitude and Phase for Zin

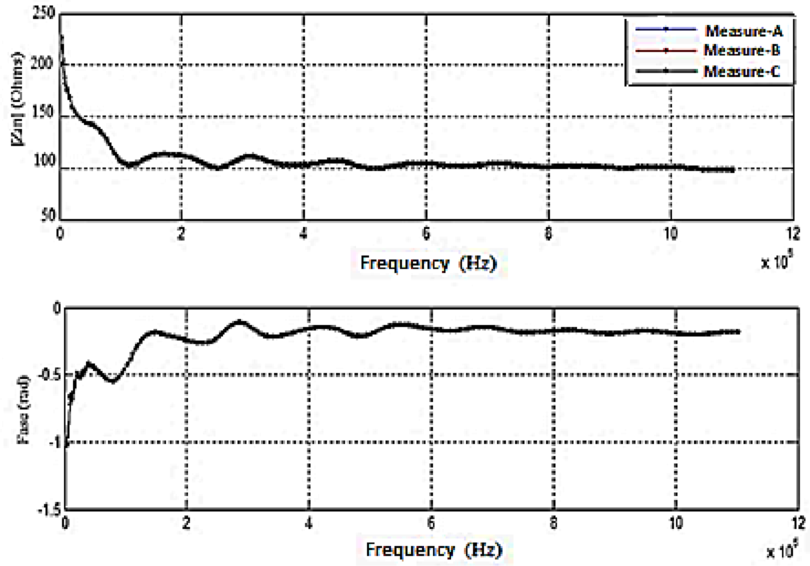

Figure 12: ETSI # 8 - Magnitude and Phase for Zin.

As can be observed, the curves of the three measurements A, B and C show the same behavior for both the magnitude and the phase of the transfer function, scatter parameter and input impedance. These are the expected results, since the same procedures were used for the three measurements. In order to confirm that the suggested measurement procedure was consistent, the results were submitted to statistical analysis. From this analysis, we can observe the low number of outliers, the low standard deviation and the value of the associated uncertainty, in the three measurements, as shown in Table 3. It concludes the coherence of the data obtained through the application of the methodology proposed in this work.

Table 3. Results of Statistical Analysis of Measurements

Link	Percentage of Outliers (%)	Standard deviation (dB)	Uncertainty (dB)
Statistical analysis of the measurements H (f)			
ETSI#1	6,5	0,0503	0,1340
ETSI#8	3,9	0,0189	0,0554
Statistical analysis of S11 measurements			
ETSI#1	7,7	0,0140	0,0442
ETSI#7	7,3	0,0144	0,0453
Statistical Analysis of Zin Measurements			
ETSI#1	8,1	0,7337	1,9191
ETSI#8	9,5	0,8955	2,3423

5.1 Sensitivity of Measurements

As described in the objectives, some adverse situations can cause errors in the measurement results, due to the sensitivity they are subject to. These situations directly affect the outcome of one or more measurements. The most common errors encountered often arise from the incorrect use of some or more procedures performed during the measurement.

In the first situation, calibrations that were not adequate for the test were performed. Thus, three measurements of the transfer function were used for the ETSI #8 standard link. The choice of this link was only a way of showing the result, which such a situation causes in these measurements. However, the same situation can be evidenced in any link of the subscriber. Figure 13 shows the average curve of the three incorrect measurements when the appropriate calibration type versus the average curve of the same measurements is not used when using the correct calibration.

In the second situation, three measurements of the transfer function for standard ETSI # 8 binding were also used. Figure 14 shows the average curve of the three incorrect measurements when neither a calibration procedure nor a mean curve of the same measurements is used when using the correct/proper calibration procedure.

In the third situation, the error that an imperfect connection can cause in the results of one or more measurements becomes clear. Three measurements of the transfer function were also used for the ETSI # 8 standard link. Figure 15 shows the average curve of the three incorrect measurements versus the average curve of the same measurements when all measurement instruments have perfect connections.

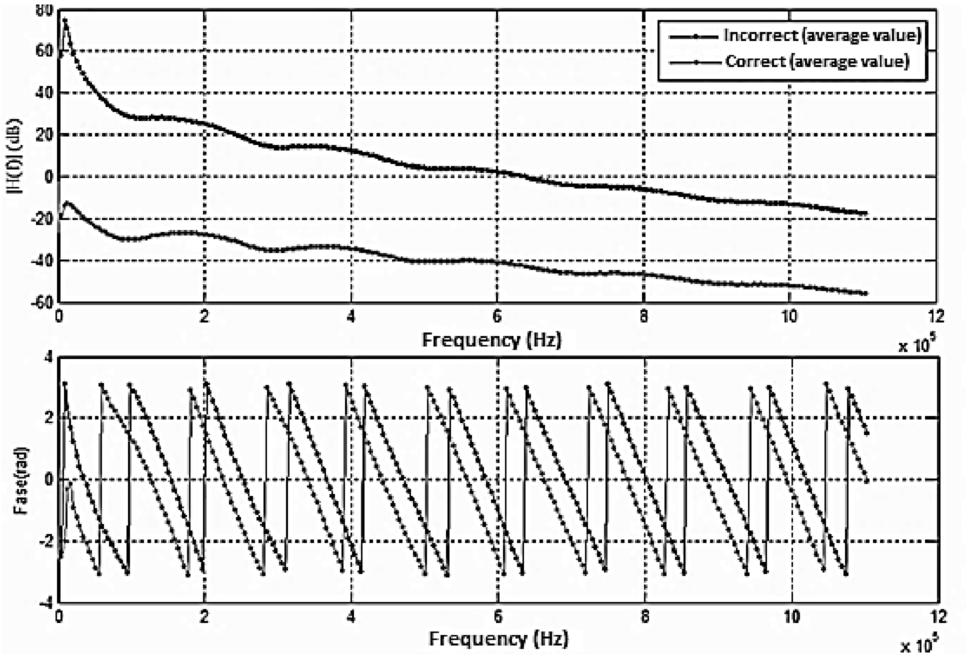

Figure 13: ETSI # 8 - Mean Correct x Incorrect Corrections

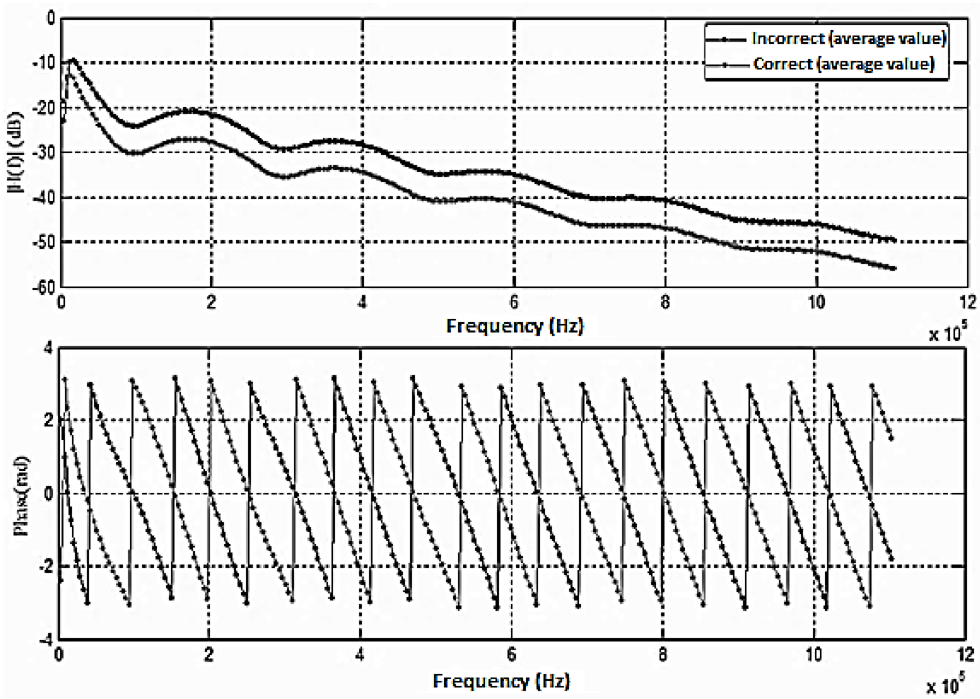

Figure 14: ETSI # 8 – Mean curve Correct x Incorrect Corrections

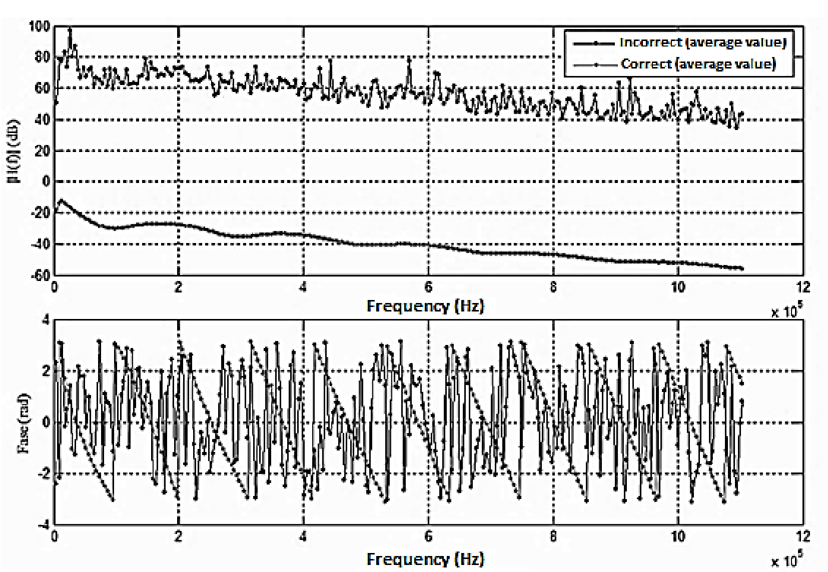

Figure 15: ETSI # 8 - mean curve incorrect x measurements correct

Table 4 shows the results of the statistical analysis of the three situations described above.

Situation	Percent Outliers (%)	Standard deviation (dB)	Uncertainty (dB)
1	7,7	0,0184	0,0544
2	10,2	0,0206	0,0593
3	8,6	0,0192	0,0560

Table 4: Statistical Analysis of H (f) Measurements for ETSI # 8 link.

VI. Conclusion

DSL technology is increasingly close to that of small and medium-sized residential and commercial users as a source of broadband Internet access. Compared to other broadband Internet access services such as fiber optics, cable and wireless, DSL technology is characterized by the need for a short installation time and activation of the service, since it uses the existing telephone infrastructure, in addition to the low investment to acquire the DSL modem. By this methodology, it has been found that the important steps in the measurement process are:

1. Properly choose the devices that make up the measurement setup, observing the technical characteristics as well as their influence on the measurement process.
2. Use a calibration process appropriate to the measurement procedure.
3. Use statistical treatment to observe consistency of results.

The use of the proposed methodology, when performed in an appropriate way, allows the data obtained in the measurements to be used for many purposes. Among these purposes, we highlight the validation of line models through computational simulations, parameter estimation techniques for a certain unknown link, new methodologies for link qualification based on advanced computational techniques and methodologies for the detection of bridged tap (derivations).

The results of the measurements for a real cable are compared with the results for wireline simulators. The measurements of transfer function presented sensitive differences between the simulators and the real cable, possibly due to the increase of the parasitic components in high frequencies for the real cable. For the transfer function measurement, physical characteristics and environmental conditions has great influence in final results.

Additionally, the wireline simulators meet the requirements of international DSL standards [9], resulting in a natural difference between real cable and wireline simulator measurements for transfer function parameter.

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References

[1]. T. Starr, J. M. Cioffi., And P.J. Silverman, "*Understanding Digital Subscriber Line Technology*," Upper Saddler River, NJ: Prentice Hall, 1999.

[2]. JUNIOR, E. B. *Methodology for the Measurement of Parameters Related to the Qualification of the Subscriber's Digital Link*, 2007.

[3]. DSL. Available at: http://en.wikipedia.org/wiki/DSL. Accessed on 10/2018.

[4]. International Telecommunication Union - Telecommunication G.992.1, "Asymmetrical Digital Subscriber Line (ADSL) Transceivers", 2018.

[5]. JUNIOR. B. Edson, L. V. Souza, Castro L. S. Agostinho, et al. "*A Methodology for Measurements of Basic Parameters in a xDSL System* ", *Broadband Access Communication Technologies, SPIE Vol. 6390 63900M-1*, October, 2006.

[6]. Agilent 4294A Precision Impedance Analyzer. "Operation Manual". Sixth Edition. Japan, May 2018.

[7]. Agilent Technologies White Paper. "ADSL Copper Loop Measurements", 2018.

[8]. S. G. Rabinovich, "*Measurement Errors and Uncertainties*", Springer-Verlag, Second Edition, 1999.

[9]. "Choosing a Wireline Simulator", White Paper, Spirent Communications, 2018.

[10]. Bostoen Tom, Boets Patrick**,** "Estimation of the Transfer Function of a Subscriber Loop by Means of a One-Port Scattering Parameter Measurement at the Central Office". IEEE.2002.

[11]. Galli Stefano, Kerpez J. Kenneth, "Single-Ended Loop Make-Up Identification. Part 1: ANovel Maximum Likelihood Algorithm". IEEE, June, 2003.

[12]. S. Galli, and D. L. Waring, "*Loop Makeup Identification Via Single Ended Testing: Beyond Mere Loop Qualification", IEEE Journal On Selected Areas in Communications, Vol.20, No. 5*, June 2002.

[13]. Biesen Van Leo, Boets Patrick, Louge Frank, Bostoen Tom, "Experts System for the Identification and Classification of the Local Loop". IMEKO, June 2004.

[14]. P. Golden, H. Dedieu, K. Jacobsen, "*Fundamentals of DSL Technology*", AuerbachPublications, 2006.

[15]. Galli Stefano, Kerpez J. Kenneth, "Single-Ended Loop Make-Up Identification – Part II:Improved Algorithms and Perfomance Results". IEEE Communications Magazine, April2006.

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