New Measurement Requirements for Telecommunications Transformers

With increased use of the Internet and mobile communications has come the need to transmit digital information at higher speeds. This need has put new requirements on transformer manufacturers and presented new challenges to test equipment designers. This paper looks at the new measurement requirements and provides a technical overview.

The measurements looked at in this paper include; Total Harmonic Distortion (THD), Insertion Loss (IL), Return Loss (RL), Longitudinal Balance (LB) and Transverse Balance (TB).

Background

Transformers can be grouped into two broad classes - Power and Signal Transformers. Linear power transformers generally operate at a single line frequency, and high drive levels, SMPS (switch mode power supplies) require transformers to work under similar conditions at higher frequencies. Signal transformers are required to operate from low to high drive levels and multiple frequencies; they have been traditionally used to transmit signals at audio frequencies. However in recent years the requirement has been changing to transmit high-speed digital data. Typical technologies today include ISDN, HDSL and most recently ADSL.

Telecom Transformer Measurements

Total Harmonic Distortion (THD)

A critical measurement for digital line matching transformers and always asked for by transformer designers. THD can be measured using the technique shown below. By applying a very low distortion signal at a known frequency to the DUT and then making a series of measurements, at the fundamental frequency and the harmonics, to the fifth, across the output load, it is possible to calculate the THD. A telecommunications transformer with a poor THD will result in a distorted output signal. Telecommunication transformers require very good THD performance of typically 80–90dB. THD is also required to be measured in the presence of small amounts of DC bias current, which can significantly affect the distortion performance of the transformer.
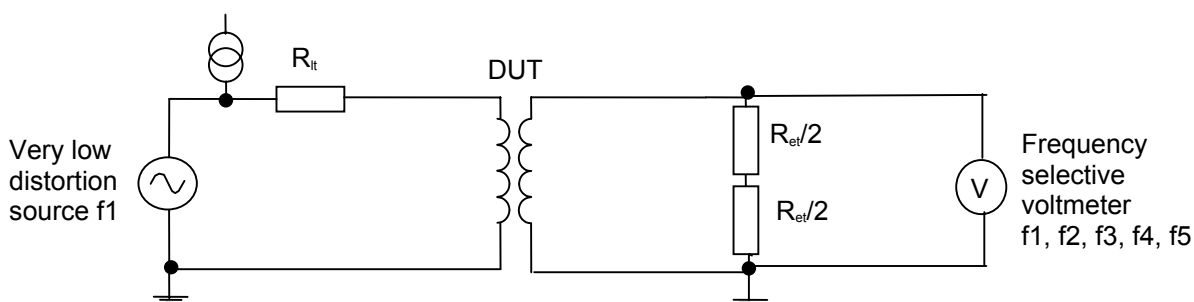
$$\text{Total Harmonic Distortion} = 20 \, \text{Log} \left(\sqrt{V_{(f2)}{}^2 + V_{(f3)}{}^2 + V_{(f4)}{}^2 + V_{(f5)}{}^2} \, / \, V_{(f1)} \right)$$

Insertion Loss (IL)
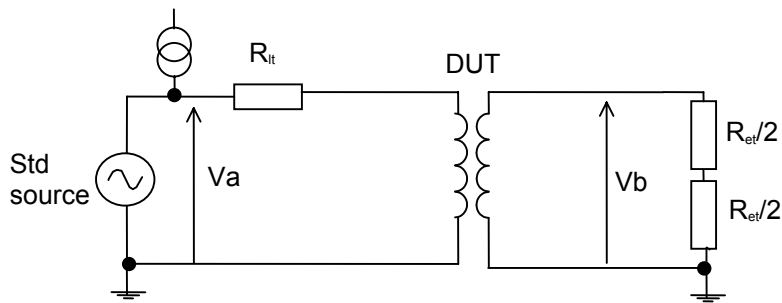
$$\text{Insertion Loss} = 10 \log_{10} (V_a^2 R_{et} / 4V_b^2 R_{lt}) \text{ dB.}$$

Insertion Loss is the ratio of the maximum power available at the source to the power delivered to the load with the transformer inserted in to the circuit. By measuring IL with the above method the result shows the total loss. This includes the true dissipated losses caused by the transformer and the losses as a result of any impedance mismatch at the input. The other advantage of this method is that, because the source and load impedance does not have to match, the turns ratio does not have to be one to one.

Insertion Loss is a measure of the signal attenuation by the transformer. Typical IL values would be between 0.5 and 1.5dB. 1dB equates to a signal power loss of approximately 20%.

Return Loss (RL)

Return Loss is a comparison of the reflected power and incident power caused by an impedance mismatch between the line and DUT. An RL value of 0dB would mean that 100% of the signal passed to the DUT had been reflected.
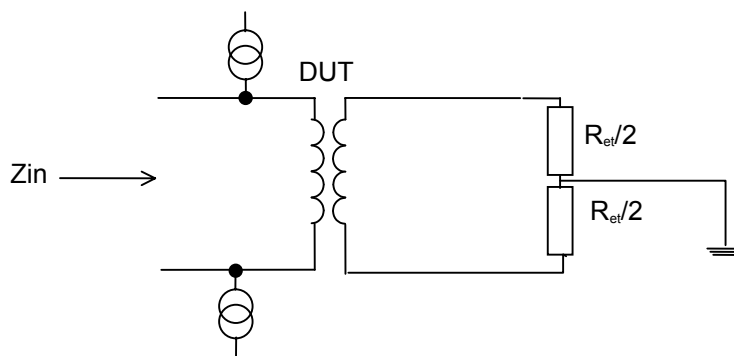

$$\text{Return Loss} = 20 \log_{10} (|Zo + Zin| / |Zo - Zin|) \text{ dB.}$$

Balance measurements

The term Longitudinal (Transverse) Balance is often used to describe two slightly different tests. The first Transverse Balance (also called Longitudinal Transverse Balance) and the second Longitudinal Balance. Both are used to test the transformers winding symmetry with respect to ground. A poor winding symmetry will result in hum, imbalance related noise and crosstalk. Balance is expressed as a ratio in dB's. It is the ratio of the metallic (differential) signal with respect to the longitudinal (common mode) signal appearing between the transformer's winding and ground.
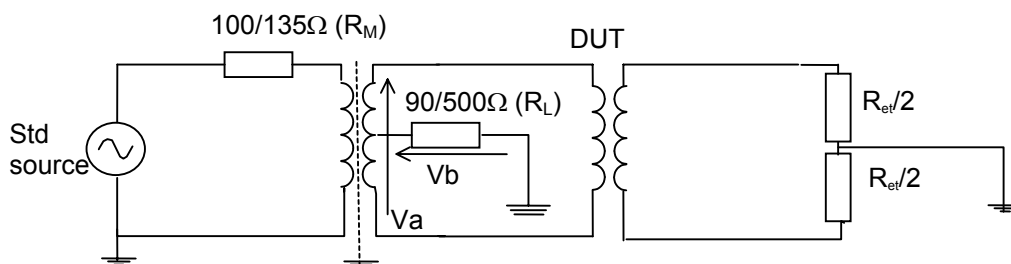
LF Transverse Balance (Analogue voice band)
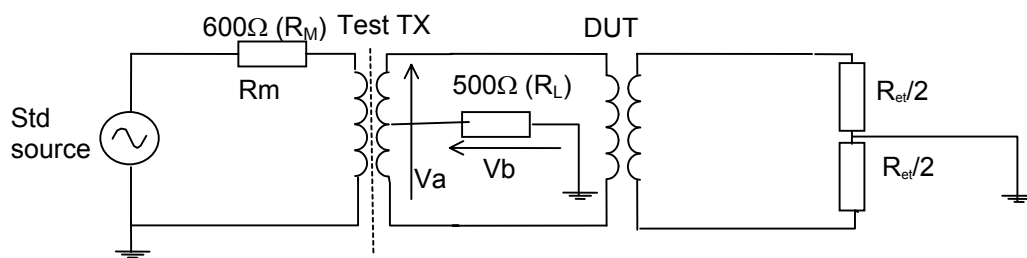
$$\text{Transverse Balance} = 20 \log_{10} (Va/Vb) \text{ dB}$$

The above method is based on the FCC68.310(a) standard. A test transformer is used to apply a balanced voltage to the DUT. Any out of balance impedance to ground causes a current to flow in R_L, generating the voltage Vb.

HF Transverse Balance (Digital)

$$\text{Transverse Balance} = 20 \log_{10} (Va/Vb) \text{ dB}$$

The above method is based on FCC68.310(b). This test is carried out in a similar way to the method used in LF Transverse Balance. The only differences being that the metallic (R_M) and longitudinal (R_L) impedance values are selectable and the standard transformer is replaced with a transformer that is more suitable for the higher frequencies involved.

Longitudinal Balance (Analogue voice band)
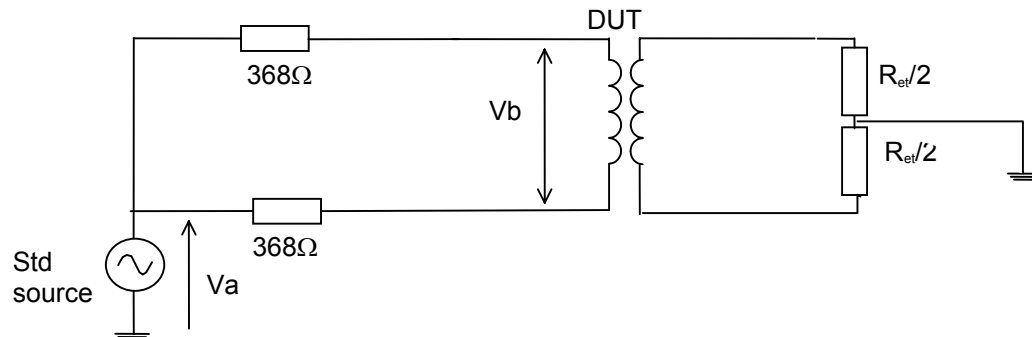
Longitudinal Balance = $20 \log_{10} (Va/Vb)$ dB

The above method is based on ANSI/IEEE455 1985. By applying the longitudinal voltage Va to the DUT, in the way shown, and then measuring the signal at Vb, it is possible to detect the imbalance caused by the DUT..

Conclusion

Line matching transformers used for xDSL applications require more complicated and varied measurements than their predecessors. Whilst requiring the more usual parametric measurements such as winding inductance, DC resistance and leakage inductance, they also require Total Harmonic Distortion, Longitudinal and Transverse Balance, and Insertion and Return Loss. The challenge for the test equipment designer has been to develop a test solution able to provide all the required measurement capability in an integrated package whilst reducing the complexity and uncertainty of the measurements to the user. Wayne Kerr Electronics have achieved this with their 3261A Telecom Unit. It provides all the measurement capability identified in this paper, meets the stringent specifications of the relevant standards, reduces measurement complexity using software trims and corrections, and does so in an integrated unit. All the measurements are taken using a single terminated fixture allowing for the first time measurements such as Total harmonic Distortion and Longitudinal and Transverse Balance to be made in a production environment.

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