TR-41 – TELECOMMUNICATIONS TERMINAL EQUIPMENT

Technical Subcommittee TR41.9 - Technical Regulatory
Reno, Nevada; November 9th, 1999

CONTRIBUTION

TITLE: **Transverse Balance Issues & Testing**

SOURCE*: **Lucent Technologies**

PROJECT: **T1E1.4 Spectral Compatibility**

ABSTRACT

Transverse balance measurement philosophy and issues with the current techniques as summarized in Part 68 are examined. In addition, a more accurate and reliable test apparatus with associated calibration techniques and conversion tables is offered to address problems with the current approach.

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1 Introduction

Transverse Balance is defined in FCC Part 68[1] as $20\log(e_M/e_L)$. This coefficient represents the ratio of the metallic e_M to longitudinal e_L voltage in a tip ring circuit expressed in dB.

Longitudinal currents arise from power influence through outside sources, such as AC induced voltage. These currents always exist on the loop to some extent. Longitudinal balance, often considered the balance of the loop itself, is typically calculated from measured values of circuit noise and power influence[2]:

Circuit Balance (dB) = Power Influence (dBrnC) - Circuit Noise (dBrnC)

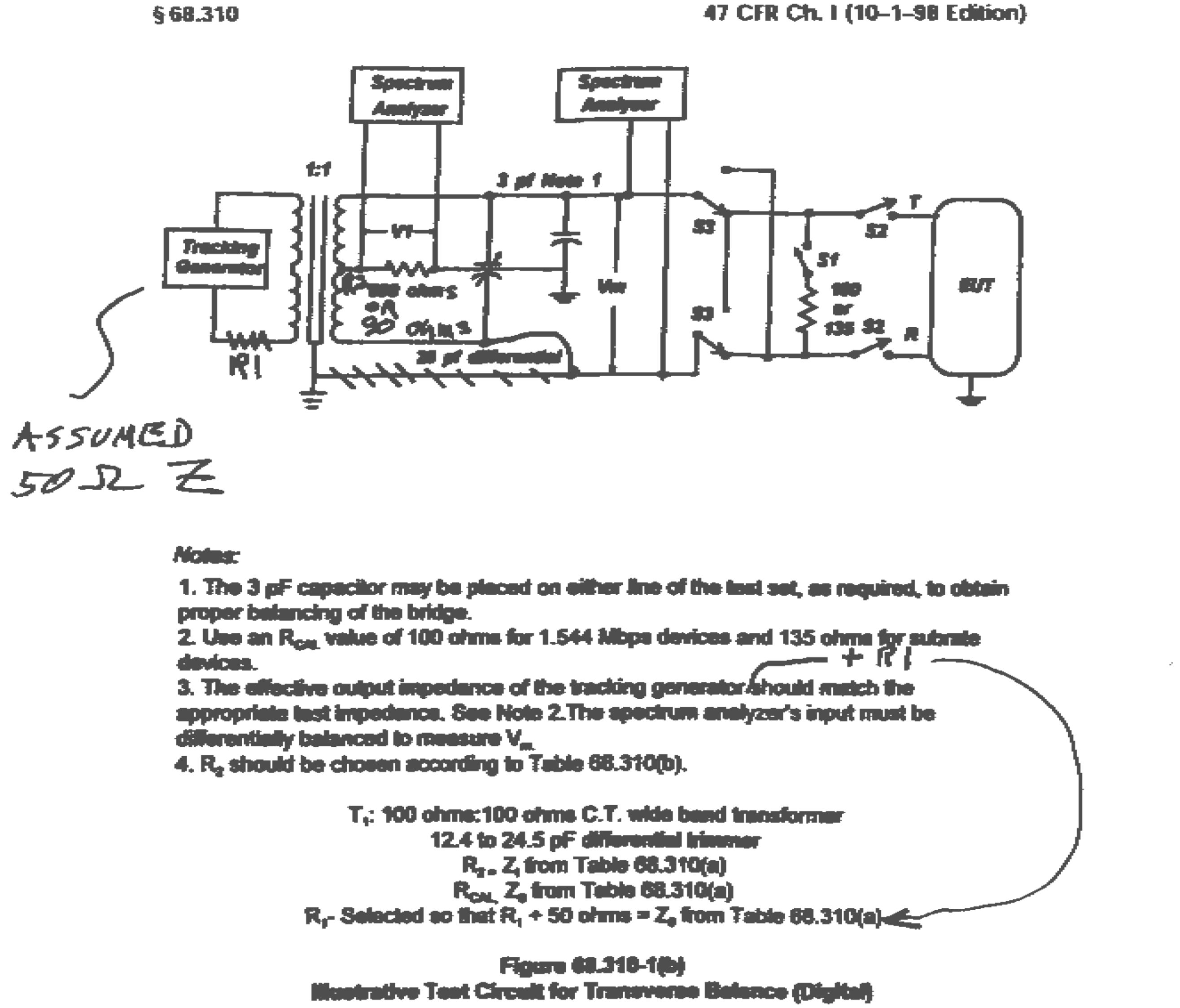
In contrast, Transverse balance measures the conversion of metallic currents in terminal equipment to longitudinal currents that could be injected into the loop and disturb adjacent circuits.

2 Part 68 & Spectrum Management Test Apparatus

An "illustrative test circuit," 63.310-1(b), for digital transverse balance conformance testing, as it currently appears in Part 68, is shown below in Figure 1. This circuit is promoted for testing digital circuits with bandwidth extending from voice range through 1.5444 Mbps. There are several issues with in this diagram:

1. Resistor R1 has not been included.
2. Note 3 provides no reference to R1.
3. R2, the longitudinal termination, is not identified.
4. $R_{CAL,}$ the resistor connected by S1, is not identified.
5. It's not necessary to use a spectrum analyzer or selective voltmeter to measure the metallic voltage; the level is high enough to use any high impedance voltmeter with adequate frequency response.
6. To measure the voltage across R2, a selective device is generally required; however, R2 is grounded, and therefore the device need not be balanced.
7. Given the differential capacitor the 3pF capacitor seems unnecessary.

Part 68 Transverse Balance Test Apparatus



§ 68.310 47 CFR Ch. I (10–1–98 Edition)

Notes:

1. The 3 pF capacitor may be placed on either line of the test set, as required, to obtain proper balancing of the bridge.
2. Use an R_{CAL} value of 100 ohms for 1.544 Mbps devices and 135 ohms for subrate devices.
3. The effective output impedance of the tracking generator should match the appropriate test impedance. See Note 2.The spectrum analyzer's input must be differentially balanced to measure V_m.
4. R_2 should be chosen according to Table 68.310(b).

T_1: 100 ohms:100 ohms C.T. wide band transformer
12.4 to 24.5 pF differential trimmer
R_2 = Z_l from Table 68.310(a)
R_{CAL} Z_o from Table 68.310(a)
R_1- Selected so that R_1 + 50 ohms = Z_o from Table 68.310(a)

Figure 68.310-1(b)
Illustrative Test Circuit for Transverse Balance (Digital)

Figure 1

3 Proposed Transverse Balance Test Apparatus

This attempt for improvement is consistent with the guidelines of Part 68 on transverse apparatus [5]:

> *…other means may be used to determine the transverse balance coefficient specified herein, provided that adequate documentation of the appropriateness, precision and accuracy of the alternative means is provided by the applicant.*

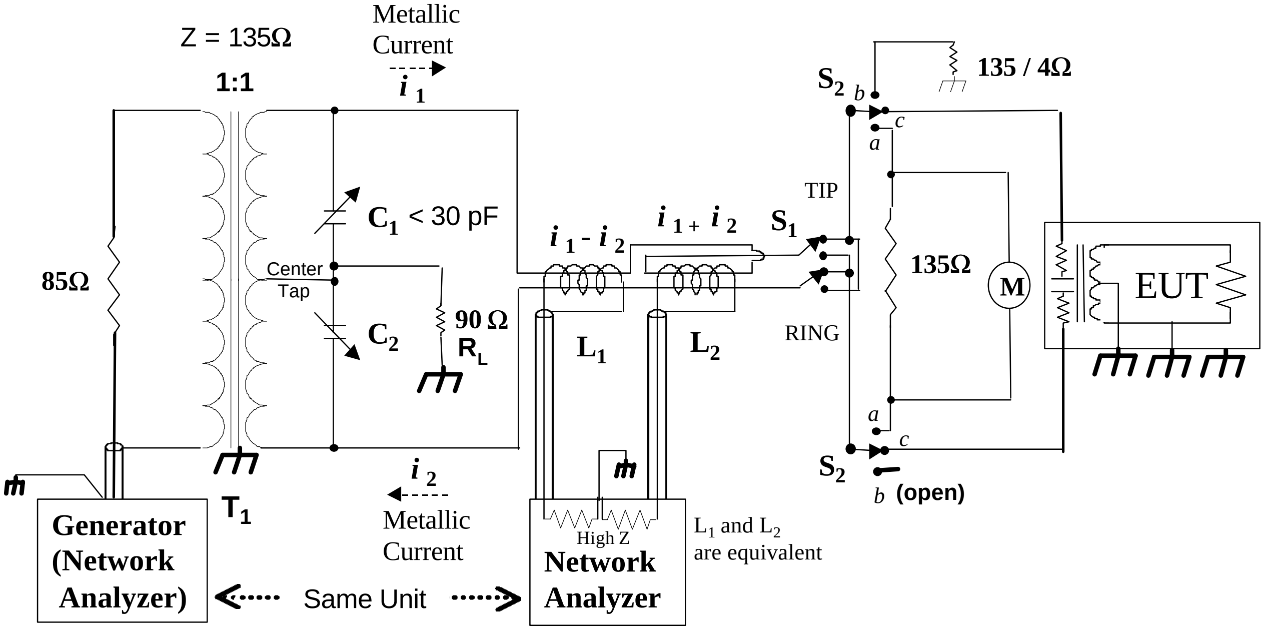
Design of test apparatus to measure transverse balance should take into account an appropriate figure of merit. The current instantiations in Part 68 rely on voltage measurements; however, as frequency increases, parasitic elements, such as capacitors and resistors, can affect the measurement. Consequently, the notion of simple extrapolation of the present Part 68 transverse balance test apparatus to higher frequencies using linear thresholds is flawed.

Conversely, in return loss testing, the limiting case is part of the calibration. That is, the worst possible termination lies somewhere between a short and open. Subsequent measurements are then used to determine how well the device performs relative to the worst case. Success is defined when it differs by some performance (20 dB of effective return loss) at normal impedance versus the extreme.

An alternate approach is to devise a current model, measuring tip and ring magnetic flux, to minimize disruption to the test configuration by outside elements and create a test apparatus with more precision and greater repeatability. Such a model is proposed in Figure 2.

Transverse Balance Test Apparatus

$$\text{Transverse Balance} = 20\log\left|\frac{i_1 + i_2}{i_1 - i_2}\right|$$



- Current measuring modem rather than a voltage measuring model
- Depending on orientation of L1 and L2, metallic current cancels and longitudinal current sums
- Absence of longitudinal coupling indicates a better transverse balance

Figure 2

Here, two variable capacitors C_1 and C_2 balance the residual impurities of the 2 windings of T_1. Parasitic effects of components in the circuit when equal and opposite will cancel. As such, no calibration is required and the resulting low impedance signal measured is more sensitive than the EUT. The measurement method achieves the basic goal of quantifying lost current that doesn't flow equally through tip and ring across the frequency of interest.

4 Conversion of Results to Voltage Ratio

Since the test circuit excitation voltage, V_M; and longitudinal termination impedance, Z_{LT} (R_{LT}) are the same as those used as in the voltage ratio tests required by FCC Part 68 Rules, the current ratio measurement results from the proposed new method may be readily converted to equivalent FCC results. In Figure 2, the current measured by the right hand toroidal current sensor, denoted $i_1 + i_2$, is in fact *twice* the metallic current, I_M. Similarly, the current measured by the left-hand sensor, denoted $i_1 - i_2$, is *exact*ly the longitudinal current, I_L. Clearly, we can express the voltage ratio, called VRATIO below, as:

$$VRATIO = \frac{|I_M||Z_M|}{|I_L||Z_L|} = \frac{|I_M||Z_M|}{|I_L|R_{LT}} = \frac{|V_M|}{|V_L|}$$

Equation 1

Equation 1 can be written:

$$VRATIO = \left(\frac{|Z_M|}{R_{LT}}\right)\left(\left|\frac{I_M}{I_L}\right|\right) = \left(\frac{|Z_M|}{R_{LT}}\right)\frac{IRATIO}{2} = \frac{1}{2}\left(\frac{|Z_M|}{R_{LT}}\right)IRATIO$$

Equation 2

Where IRATIO is the ratio measured by the test apparatus and used in the Transverse Balance equation of Figure 2. In other words, the FCC voltage ratio is obtained (before taking the log) simply by multiplying the current ratio by 1/2 the ratio of the magnitude of the DUT's metallic impedance to the value of R_L. R_L fixed, real, and known, and the magnitude of Z_M is either known or easily measurable, and will often be nearly constant over the frequency band of interest. Equation 2 is expressed in logarithmic form:

$$VRATIO_{dB} = \left[20Log\left(\frac{|Z_M|}{R_{LT}}\right) - 6.02dB\right] + 20Log(IRATIO)$$

Equation 3

The first term in Equation 3 is the necessary correction factor. For $Z_M = 135\ \Omega$ and $R_L = 90\ \Omega$, the factor is –2.50 dB; for $Z_M = 100\ \Omega$ and $R_L = 90\ \Omega$, it is –5.10 dB.

Equations 2 and 3 hold, *even if the DUT is a non-linear or active device*, so long as we excite the DUT with the same metallic voltage, and use the same longitudinal termination resistance in the test apparatus as are specified for the equivalent FCC Part 68 tests.

5 Calibration of High Frequency Transverse Balance Test Apparatus

Note S_2 in figure 2 represents a two pole switch box that sets the tip and ring connections to either "a," or "b" as shown above. "a" creates a circuit with 135 ohms resistance simulating the equipment under test (EUT) and as such is a "perfect termination" case. "b" has one side grounded and the other open. This represents the worst case.

S_1 is a two pole switch box that reverses the connections for tip and ring.

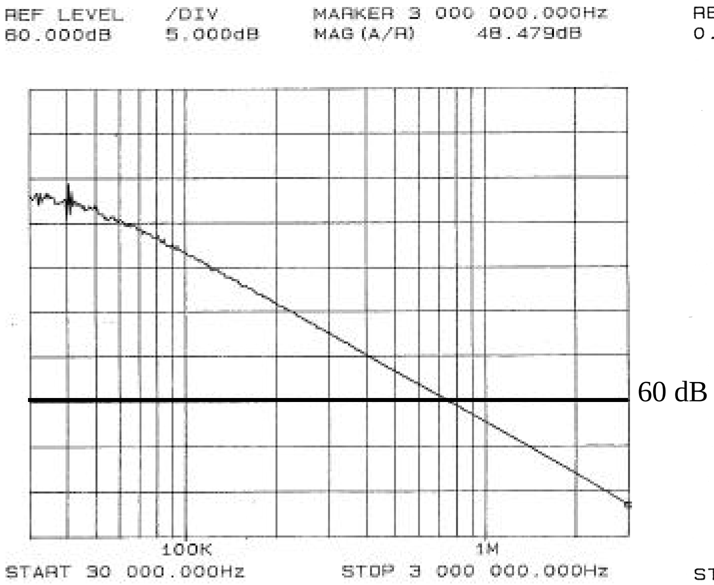
1. Remove EUT from the Tip/Ring pair and terminate the Tip/Ring pair with 135 ohms (S2 to "a"). This represents a "perfect termination" case.
2. Adjust the tracking generator voltage to measure -10dBV (316mVrms) across the Tip/Ring pair.
3. Adjust C_1 and C_2 to obtain maximum transverse balance. Note that transverse balance shall be defined as follows: Transverse Balance = $20\log|(i_1+i_2)/(i_1-i_2)|$. The result of this balance calibration shall be at least 20dB better than the requirement for the applicable frequency band.
4. Reverse the polarity of the Tip/Ring pair at S_1. If the transverse balance changes by more than 1dB, the test circuit needs further adjustment to improve its measurement accuracy.
5. Terminate the Tip connection with 33.75-ohm resistor and the Ring connection to ground (S_2 to "b"). Verify that the transverse balance measurement is less than 1dB. Reverse the polarity of the Tip/Ring pair at S_1. Again, verify that the transverse balance measurement is less than 1dB. If both conditions are not met, the test circuit needs further adjustment to improve its measurement accuracy.

6 Conclusion

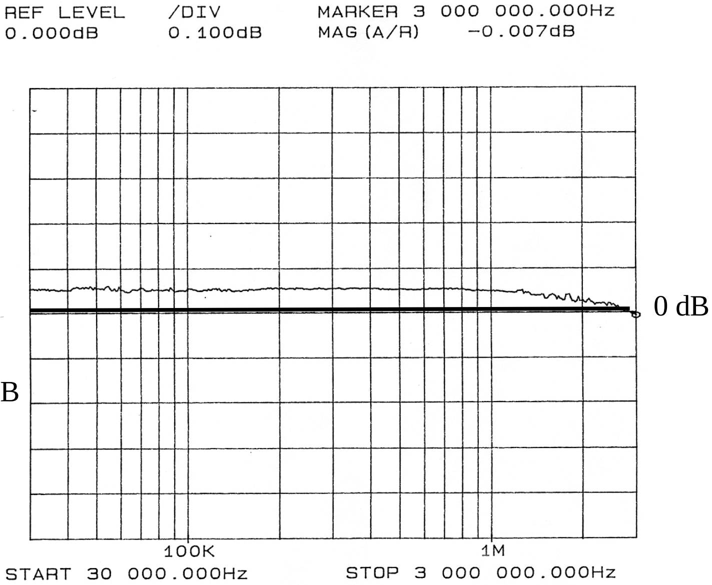
A better mechanism for measuring transverse balance has been presented that is simpler, more accurate and can extend to frequencies spectral classes of DSL require. This apparatus should be considered as a standard apparatus used in transverse balance test procedures.

Annex A - Calibration Examples

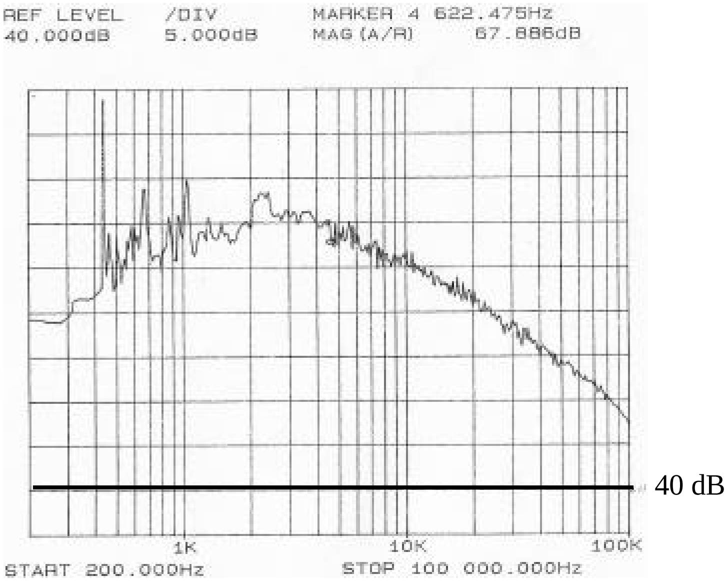
Short to 135 Ohms



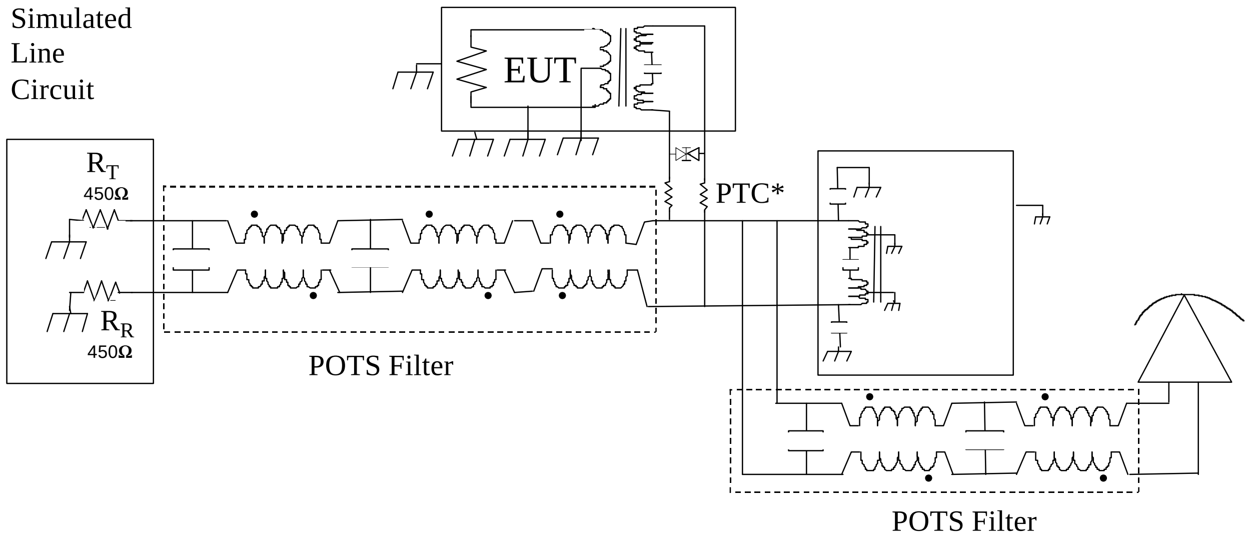
Open



Passing Device



Annex B - Reference DSL Test Circuit



* Positive Temperature Coefficient Resister

References

[1] Federal Communications Commission Rules and Regulations, Code of Federal Regulations Title 47: Part 68 - Connection of Telephone Equipment To The Network. Section § 68.310, pg. 315

[2] Subscriber Loop Signaling and Transmission Handbook, Reeve, 1992, IEEE Press

[3] T1E1.4/99-356, "Proposed Text for Transverse Balance Requirements in dpANS for Spectrum Management", Bell Atlantic, June 7-11, Ottawa, Ontario, Canada;

[4] Federal Communications Commission Rules and Regulations, Code of Federal Regulations Title 47: Part 68 - Connection of Telephone Equipment To The Network. Section § 68.310, pg. 305

[5] Federal Communications Commission Rules and Regulations, Code of Federal Regulations Title 47: Part 68 - Connection of Telephone Equipment To The Network. Section § 68.310, pg. 315