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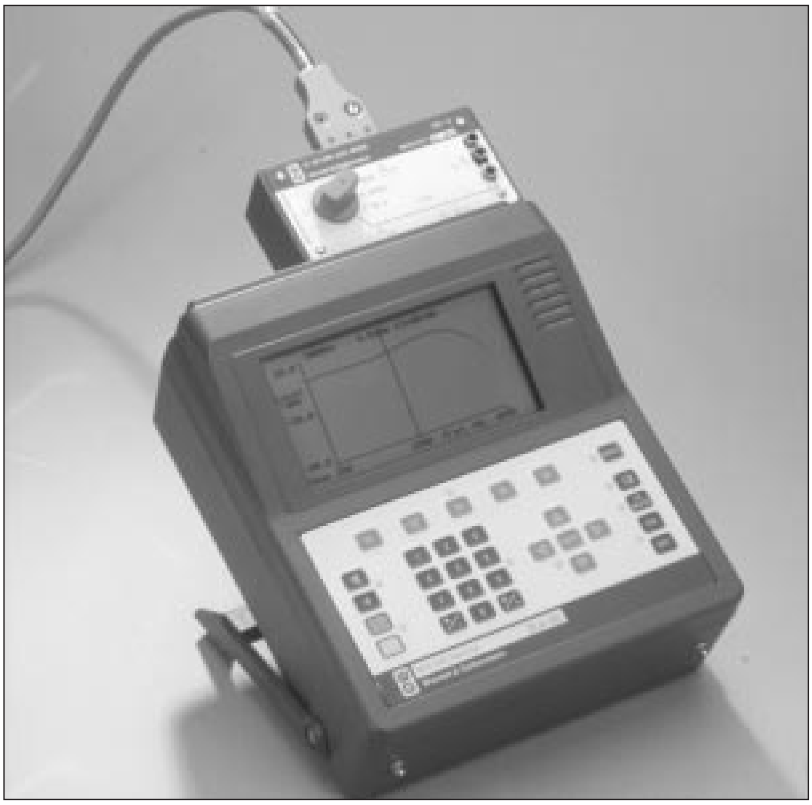
Return Loss Measurements Using DLA-9D

Application Note:

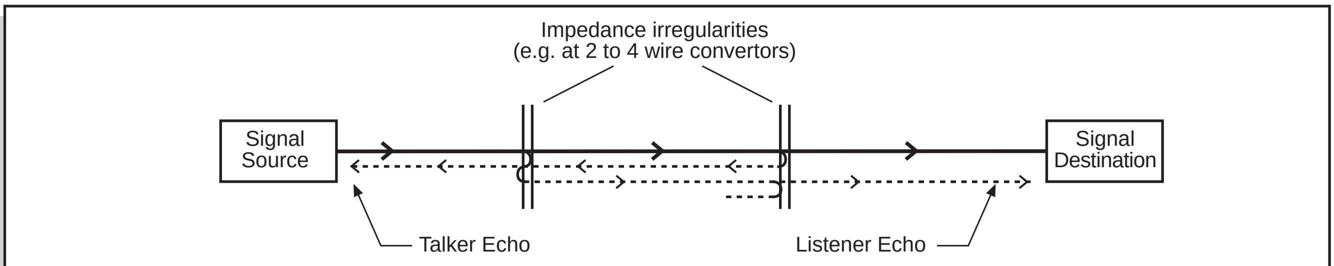


Summary

DLA-9D will measure Return Loss at 1kHz. The VRL-6 accessory allows the DLA-9D to perform a swept return loss measurement on a 2 wire circuit.

This application note discusses return loss problems, definitions and measurement with DLA-9D.

What is the Problem?



Echo Paths on a Transmission Line

Impedance mismatches in communications circuits cause problems because signals are reflected back to the source from each mismatch. This can result in a loss of power transfer and interference with, or corruption of, the signal.

When a signal is reflected it arrives back at the sending end as an echo (talker echo). A double reflection will arrive as a delayed signal at the receiver (listener echo). This is a problem on voice circuits as it reduces the intelligibility of speech, and for data circuits the echo signals can interfere with the data causing errors.

On relatively short circuits the echo arrives within a few microseconds as a phase shifted signal, so the effect is a change in power transfer and can be measured as a Return Loss figure. Phase shift modulation techniques used in modern modems can be badly affected by interference from echoes.

In extreme cases the echo signal may be 360° phase shifted and add to the original causing instability or ‘singing’ on the line.

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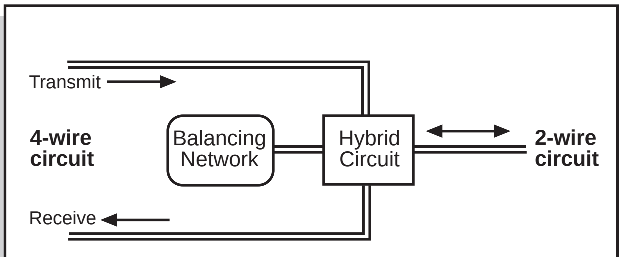
As circuit path lengths increase and switch and digital codec delays are introduced, the actual end-to-end or round trip delay can become significant - up to a few seconds if geo-stationary satellite hops are included. Apart from the annoying effect of the basic delay, these delays are added in the echo signals causing further confusion on speech circuits and errors in data.

In order to minimise these problems echo cancellation circuits are included on many long distance links. These echo cancelling units usually operate in the 4-wire part of the circuit and can themselves introduce further impairments in the overall transmission path.

Often problems arise where the 2-wire local loop circuit is converted into a 4-wire circuit for transmission over the network. This is the point at which the 2-wire circuit is terminated and a hybrid is used with a balancing network to minimise unwanted signals on both sides of the circuit.



2-wire to 4-wire conversion
Impedance of balancing network must match the impedance of the 2-wire circuit

For the hybrid to work correctly the impedance of the balancing network should match that of the 2-wire circuit. In practice the 2-wire impedance depends on the loop length and conditions so it is difficult to balance correctly. This results in echoes and return losses on both sides.

As well as impedance balance errors, problems can also be caused by signal balance distortions. Normally the signal is present across the pair of wires forming the circuit and should be balanced about a local earth point. If the pair is unbalanced with respect to ground then further losses and interference can be introduced.

Several different signal unbalance conditions are identified in ITU-T O.9 and can be measured using the DLA-9D with the VSM-6 accessory.

We thus have three types of distortion arising from the physical length, condition, and termination of the line - return losses, round trip delay, and signal balance distortions.

A poor return loss figure is perceived by the user as an increase in sidetone, i.e. the loudness of their own speech that they hear back through the ear piece. Some sidetone is deliberately introduced by the telephone to encourage the user to talk at a natural level, additional sidetone tends to cause the user to talk too quietly.

As a rough indication a 20dB return loss figure will cause an increase in sidetone of 1dB. An overall figure around the circuit greater than 6dB is required for stability (no singing).

What is it?
Return Loss Defined

The various standards bodies agree on the basic definition of return loss, but derive differing associated parameters that can be specified and measured in practice. This has led to some confusion across the Atlantic as the IEEE and CCITT (ITU-T) terminology differs.

European Definitions (CCITT Specification)

“Return Loss: Quantity characterising the degree of match between two impedances, Z_1 and Z_2. It is given by the expression:

$$L_R = 20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{dB} \quad ”$$

CCITT Blue Book Vol. III G.100 1.5

A note to G.122 adds the comment:
“The use of the expression ‘return loss’ should be confined to 2-wire paths supporting signals in the two directions simultaneously.”

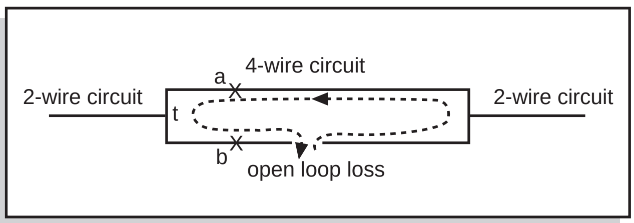
CCITT Rec.G.122 Annex B

“Open-Loop Loss (OLL): In a loop formed by a 4-wire circuit ... and terminated by 2-wire ends ..., the loss measured by breaking the loop at some point, injecting a signal and measuring the loss incurred in traversing the open loop.

Note 1 - In practice the OLL is equal to the listener echo loss (if it exceeds 8dB)

Note 2 - The OLL is also equal to the sum of the two semi-loop losses”

CCITT Blue Book Vol. III G.100 4.10



“Semi-Loop Loss: The transmission loss between points ‘a’ and ‘b’ of the 4-wire termination independent of whether there exists or not a physical point ‘t’.”

CCITT Blue Book Vol. III G.100 4.11

“Stability Loss: The lowest value of the semi-loop loss in the frequency band to be considered.”

CCITT Blue Book Vol. III G.100 4.12

“**Balance Return Loss:** At a 4-wire terminating set (‘hybrid’), that portion of the semi-loop loss which is attributable to the degree of match between the impedance, Z_{2W}, connected to the 2-wire line terminals, and the balance impedance, Z_B. It is given approximately by the expression:

$$L_{BR} = 20 \log_{10} \left| \frac{Z_{2W} + Z_B}{Z_{2W} - Z_B} \right| \text{dB}$$

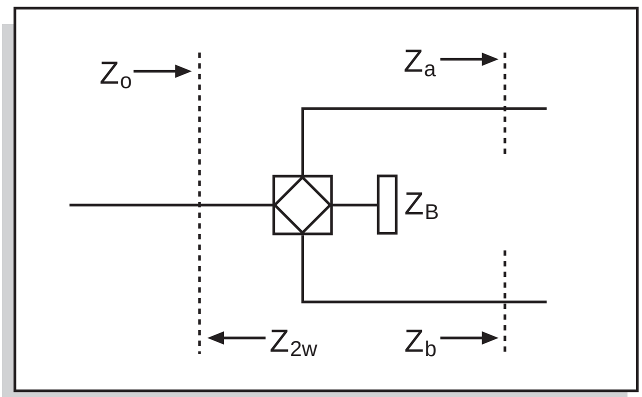
***Note :**- Under most circumstances the expression given is sufficiently accurate. However, for some worst case evaluations, the exact expression must be used:*

$$L_{BR} = 20 \log_{10} \left| \frac{Z_O + Z_B}{2Z_O - Z_B} - \frac{Z_{2W} + Z_O}{Z_{2W} - Z_B} \right| \text{dB}$$

where Z_O is the 2-wire input impedance.

(If $Z_O = Z_B$ the expression simplifies to the approximation given above) ”

CCITT Blue Book Vol. III G.100 4.1



In practice the 4-wire legs often present the same impedance (eg 600Ω)as the balance impedance.

$$Z_a = Z_b = Z_B$$

In this case $Z_O = Z_B$ and the simple expression applies.

Echo Balance Return Loss: Balance return loss averaged with 1/f power weighting over the telephone band.

CCITT Blue Book Vol. III G.100 4.3

Test Balance Return Loss (TBRL): The balance return loss measured against a test impedance (Z_{2W} is a specified test impedance)

Note - The TBRL characterises the precision of the balance network

CCITT Blue Book Vol. III G.100 4.14

“**Echo:** Unwanted signal delayed to such a degree that, for instance in telephony, it is perceived as distinct from the wanted signal.

Note 1 - Distinction is made between talker echo and listener echo

Note 2 - An echo is usually considerably delayed with respect to the wanted signal.”

CCITT Blue Book Vol. III G.100 4.2

American Definitions (IEEE 743 Specifications)

“**Return Loss** is ... a measure of the dissimilarity between two impedances, being equal to the number of decibels that corresponds to the scalar value of the reciprocal of the reflection coefficient :

$$RL = 20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{dB}$$

(where Z_1 is the complex impedance of the circuit under test and Z_2 is the complex reference impedance.)

Any return loss measurement includes two characteristics; frequency (single frequency or specified band) and configuration (2-wire or 4-wire).”

(IEEE 743-1995 p54)

The 2-wire return loss at frequency (f) is the ratio of transmitted to reflected power as given by :

$$RL(f) = 10\log_{10} (\text{ transmitted power(f) / reflected power (f) })$$

4-wire return loss measurements can be further classified according to whether adjustment is made for the effect of any amplification, pads, or a hybrid at the remote end.

The basic 4-wire return loss, called **Echo Path Loss** (EPL), is measured with the remote end connected to a hybrid with a terminated 2-wire circuit on the far side:

$$EPL (f) = 10\log_{10}(\text{ transmitted power(f) / received power (f) })$$

The unadjusted 4-wire EPL is modified to take account of any difference in the expected transmission levels at a nominal 1kHz of the sending and receiving points to give the equal level echo path loss (ELEPL). The difference is known as **Trans-Hybrid Loss** (THL)

ELEPL = EPL + (1kHz receive level) - (1kHz transmit level)
or ELEPL = EPL - THL

The trans-hybrid loss can be measured by arranging for a complete impedance mismatch (open or short circuit) on the 2-wire side of the remote hybrid and measuring the EPL. This will give the sum of the losses in the 4-wire circuit and those due to the hybrid alone. From the THL the return loss on the remote 2-wire circuit can be inferred to give the trans-hybrid loss corrected echo return loss (THLCERL) by again measuring the EPL with the 2-wire side of the remote hybrid correctly terminated and subtracting the THL.

“**Echo Return Loss** (ERL): the frequency weighted average of the return losses over the middle of the voice band, with the far end terminated with a specified impedance. The 3dB down frequencies of the weighting are 560Hz and 1965Hz.”

IEEE 743-1995 2.1.15

“Singing Return Loss (SRL): the return loss of a circuit measured with two separately transmitted signals with a flat spectral distribution between 3dB frequencies of 260Hz and 500Hz (SRL Low) and 2.2kHz and 3.4kHz (SRL High). The lower of the two return losses (SRL Low or SRL High) will be the best measure of the margin of the circuit against singing.

IEEE 743-1995 2.1.16

Thus ERL, SRL low, and SRL High are average return loss measurements over a specified band. The full designation of the measurement should include the configuration eg: ELERL, ELSRLH, 2-wire ERL.

The measurements are made either with a shaped transmitted spectrum and wideband receiver, or with a stepped or swept frequency and a calculated weighted average, or with white noise generator and a shaped spectrum receiver.

To avoid system overload and background noise the output level from the transmitter should normally be -10dBm (up to -6dBm is okay)

Definitions - Summary

There seems to be general agreement about the measurement of return loss when looking into a 2-wire circuit.

When looking at the 4-wire side of the hybrid both sets of standards attempt to distinguish between the loss due to the hybrid , and the loss due to the 2-wire circuit.

Considering the usual network configuration of a 2-wire local loop feeding a hybrid, with a balancing network and a 4-wire connection to the switched network, there are four points at which measurements may be made. At each point both the 1kHz loss and the swept frequency loss will be of interest.

- Return loss on 2-wire circuit looking out towards the subscriber. Will include effect of line impedance. 2-WIRE RETURN LOSS.
- Return loss on 2-wire circuit looking in towards hybrid - may include the effect of 4-wire circuit losses if $Z_B <> Z_a <> Z_b$. TEST BALANCE RETURN LOSS.
- Loss due to the hybrid and 4-wire portion of circuit looking from 4-wire side - may include the effect of 2-wire return loss. SEMI-LOOP LOSS/ECHO PATH LOSS.
- Return Loss on the 2-wire circuit looking out towards the subscriber across the hybrid. BALANCE RETURN LOSS/THL CORRECTED EPL

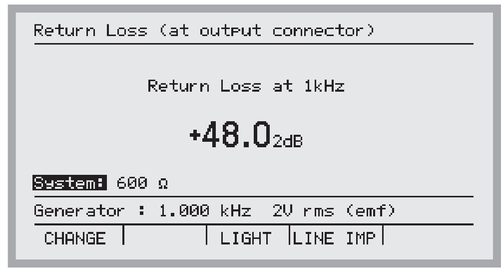
The roughly analogous measurements on each side of the Atlantic are:

ITU-T	IEEE
Semi-loop loss	Echo path loss
Balance return loss	Trans-hybrid loss corrected echo path loss
Echo balance return loss	Echo return loss
Stability loss	Singing return loss

Note that ERL and SRL only give a weighted average figure across part of the voiceband. The European combination of echo balance return loss and stability loss cover the entire voiceband.

Measuring Return Loss using DLA-9D

The basic DLA-9D will directly measure return loss on a 2-wire circuit at 1kHz using its internal reference impedance (selectable value) in the Return Loss measurement mode. Measurements of both the actual circuit impedance and the return loss are made at 1kHz 2V rms against an internal bridge.



It is desirable for 2-wire return loss to be a high figure indicating a good impedance match between the CPE and the network.

For instance, if the network impedance is 600Ω, the CPE terminating impedance is also 600Ω and the line resistance is known to be 400Ω then:

$$\text{Return Loss} = 20 \log_{10} \left| \frac{(600 + 400) + 600}{(600 + 400) - 600} \right| \text{dB}$$

$$= 20 \log_{10} (4) \text{ dB}$$

$$= 12 \text{ dB}$$

The circuit to be tested is connected to the OUTPUT/ 2-Wire connector on the rear panel. The instrument will terminate the line with a reference impedance against which measurements will be made.

With the instrument powered up press [MODE], move the highlight to the ‘Impedance/Return Loss’ option on the menu using the cursor keys, and press the <SELECT> softkey [S1].

The first page is the Line Impedance measurement page. The softkey <RET LOSS> [S4] toggles to the Return Loss page. The reference impedance can be altered with the <CHANGE> softkey [S1].

In normal 2-wire level or frequency response modes only either the generator or the receiver is switched to line so it is not possible with the base instrument to measure the 2-wire return loss at frequencies other than the standard 1kHz.

When equipped with the VRL-6 accessory, the DLA-9D can perform a swept return loss measurement on a 2-wire circuit and display the results graphically. The sweep end points, rate and step size can all be specified.

The VRL-6 provides an external 4 to 2 wire converter and reference impedances so that the DLA-9D is used in 4-wire mode to measure return loss at any frequency or level on the 2-wire circuit.

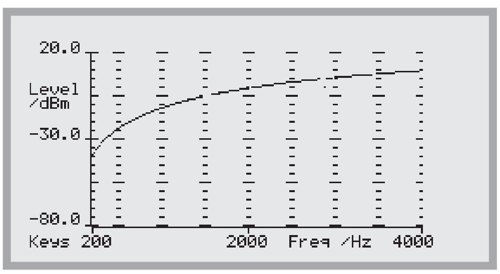
The VRL-6 is connected directly to the CF connectors on the rear of the DLA-9D. The two wire circuit under test is connected at the rear of the VRL-6. The switch on the VRL-6 allows selection of the reference impedance, and an additional CF socket allows an external reference impedance to be used if desired.

The DLA-9D is used in the 'Freq Resp/Atten Dist' mode (selected by from the menu after pressing the [MODE] key). The system parameters on the DLA-9D should be set as follows:

Tx Impedance:	~0	VRL-6 provides the line impedance
Rx Impedance:	Bridging	
System:	600	
Tx Measurement:	Absolute	
Rx Measurement:	Relative	Cancels the insertion loss of VRL-6 bridge
Rx Reference:	-6.0dBm	Adjust to give 0dB reading when VRL-6 port not connected (open circuit).
Line Type	Four Wire	Connection to VRL-6
Loopback:	On	

The generator level and sweep parameters should be set as required (typically level -10dBm and sweep 200Hz to 3.2kHz for voice circuits.

The receiver should be setup with averaging off and no mask.



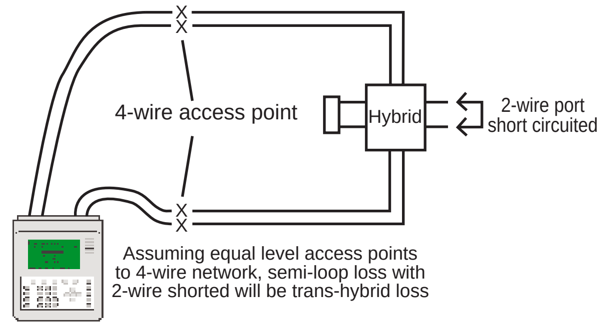
When the measurement <RUN> softkey is pressed the Level vs Frequency graph will be displayed showing the return loss against frequency. Stopping the test enables the cursor to be used to read off return loss at a particular frequency.

The Attenuation Distortion results screen has no meaning when measuring Return Loss using the VRL-6.

Once the instrument has been setup the configuration can be saved for rapid recall on future occasions. Setups can also be copied (cloned) between instruments to enable standardisation of test procedures within an organisation.

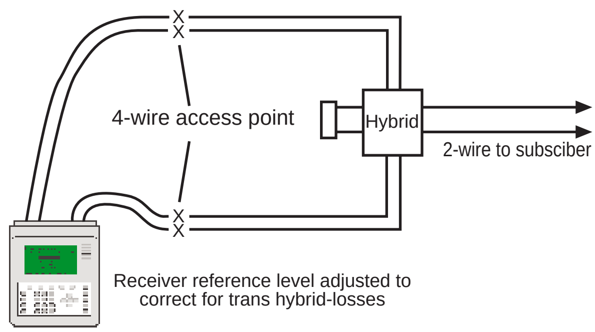
To make the 4-wire loss measurements at any frequency the base instrument is used in 4-wire mode and either a static frequency or swept frequency measurement made as required in the 'Freq Resp/Atten Dist' measurement mode.

The Balance return loss measurements indicate how much of the forward path signal is being coupled into the return path by the hybrid. This is measured by introducing a known signal and measuring the amount returned making allowance for attenuation introduced by the exchange card and the trans-hybrid losses.



DLA-9D Trans-hybrid Loss Measurement

The trans-hybrid loss is determined by shorting the 2-wire port of the hybrid and measuring the circuit loss on the 4-wire side. In the ideal case this would be -6dBm.



DLA-9D Balance Return Loss Measurement

Having determined the trans-hybrid loss the receiver should be set in relative mode and the correction applied to the Rx Reference Level to enable the Balance return loss measurement to be made directly.

The Level/Frequency graph will give a direct visual check of balance return loss across the voiceband. If necessary a weighted average can be calculated to give the Echo balance return loss and stability loss.

The IEEE ERL and SRL measurements should use a sweep between the defined end-points and a calculated weighted average. In practice this will usually give the same result as a measurement at the centre of the band (360Hz, 1kHz, or 2.7kHz).

Since the point of these swept return loss measurements is to show whether the circuit is close to oscillation, simply quoting the worst case result from the sweep will give a rapid indication of likely problems. To avoid oscillation the recommendation is for values better than -8dBm across the band.

REFERENCES: CCITT (ITU-T) G.100, 121, 122, 142 (11/88), G.712 (09/92) IEEE 743 -1995

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