Zarlink SLAC™ Devices

Applications of the Zarlink SLAC™ Devices

Interpreting Amplitude Ripple in End-to-End Frequency Response Measurements

Application Note

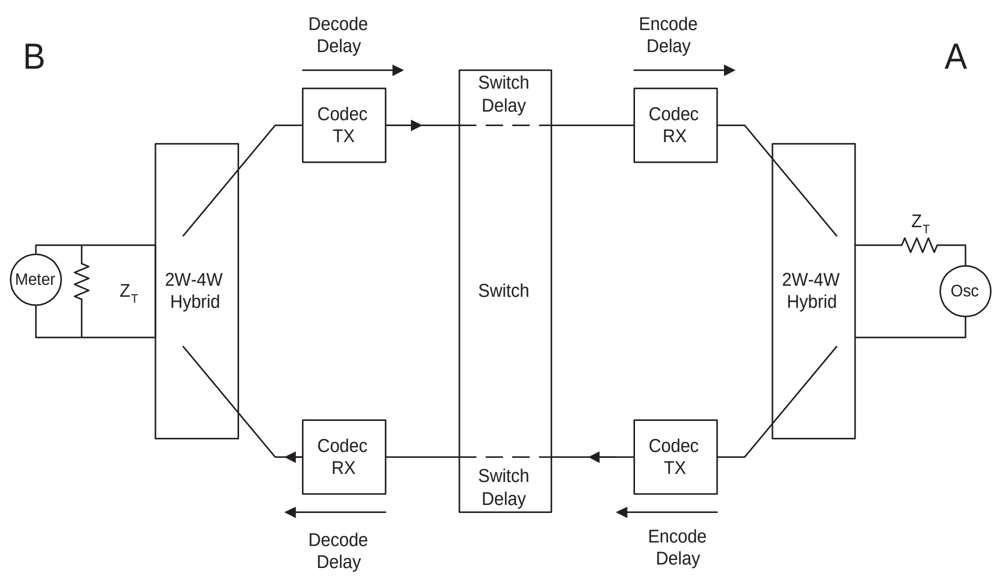
Abstract

Measuring the analog-to-analog frequency response on real world telephony channels often shows a variation in the amplitude versus frequency. This nearly symmetrical variation in amplitude occurs due to less-than-ideal, four-wire return loss, group delay and absolute delay in the connection. This variation can be used to estimate the four-wire return loss and the absolute delay.

THE FREQUENCY RESPONSE MEASUREMENT

Figure 1 shows an analog-to-analog measurement of frequency response. This measurement has the sending end's source impedance terminating the linecard which is called end *A*. The meter measuring the end *B* also has a terminating impedance. The sending level must be high enough so that noise does not influence the readings at the measuring end. The sending level must not be too high to cause clipping. Typically, these measurements are made a power level of –10 dBm. The measurement is made relative to the level received when using a frequency of approximately 1 kHz. This means that the level received at 1 kHz is always 0 dB. The level reading at other frequencies is noted relative to that taken at 1 kHz.

Figure 1. Analog Frequency Response Measurement



NORMAL MEASUREMENT CONDITIONS

The normal conditions for an end-to-end measurement use a sending end impedance that closely matches the two-wire impedance of the sending end hybrid and its four-wire transhybrid balance impedance. This condition results in a high transhybrid loss. When the transhybrid loss is low, some of the signal reaching the measuring end hybrid is fed back to the sending end. This signal is added (with a phase shift resulting from the absolute delays) to the send signal after attenuation by the send side transhybrid loss. Very low delay times and high transhybrid losses allow measurement of the frequency response of the sending end's coder and the receiving ends decoder circuits.

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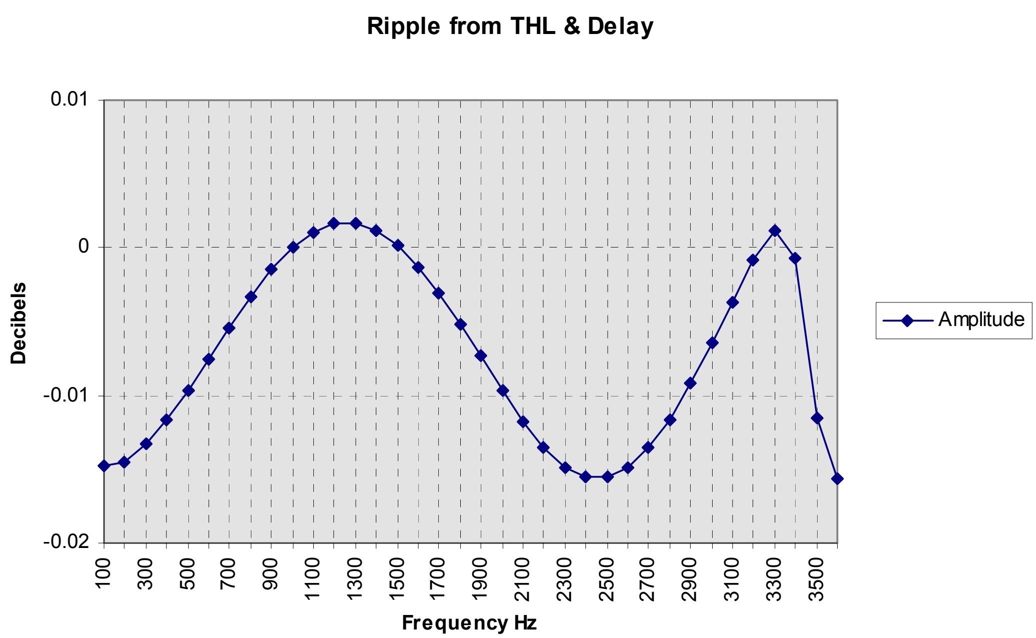
POOR TRANSHYBRID LOSS

When evaluating new telephony hardware, you may not have the correct balancing impedance or four-wire impedance programmed. If the terminations are set incorrectly, poor transhybrid loss can result. This hybrid leakage results in an apparent echo signal going around the four-wire loop. There is always a small echo signal in lab quality setups. Typical terminations such as a telephone have relatively large echo amounts. By correctly interpreting the end-to-end frequency response, you can estimate the transhybrid loss. Half-channel measurements require access to the digital PCM signal in the middle of the switch. Figure 2 shows a graph of end-to-end frequency response with good transhybrid losses.

Figure 2. Good Frequency Response Graph.

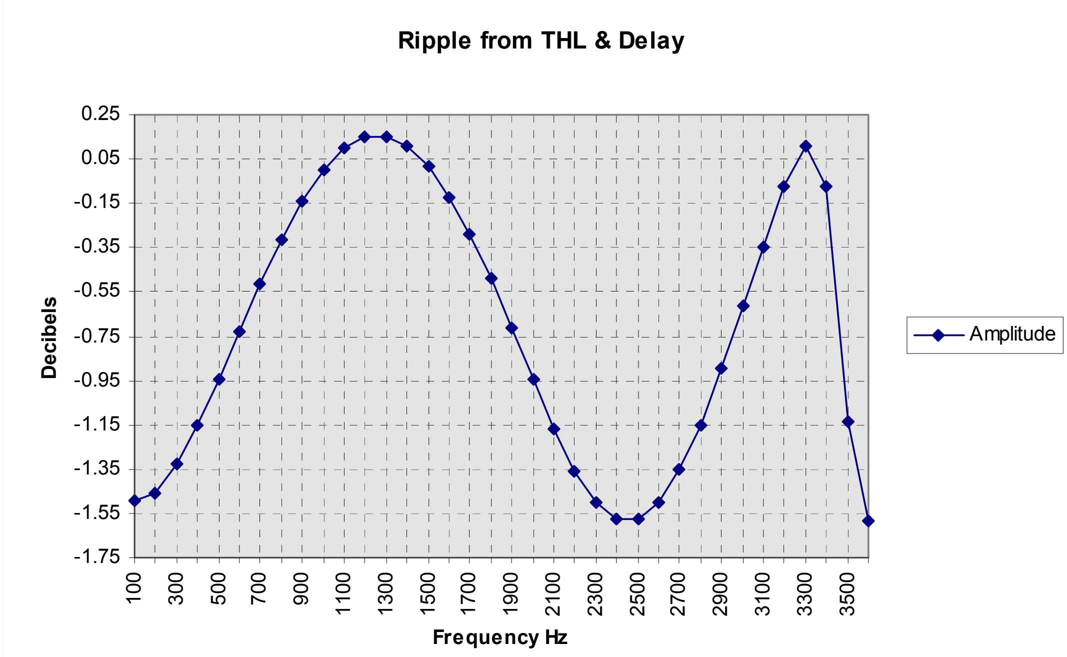


ROUNDTRIP DELAY

The amplitude of the variation in the end-to-end frequency response is mainly a function of the sum of the transhybrid losses in decibels (dB). If the delay is small this variation may be difficult to measure. Typical circuit delays produce one or more cycles of variation in the end-to-end frequency response. Figure 3 shows a graph of end-to end frequency response with poor transhybrid losses and significant roundtrip delay.

The one-way trip delay consists of the encode delay, encode filter group delay, encode filter absolute delay, decode delay, decode filter group delay, decode filter absolute delay, and switching delay. The roundtrip delay is twice the one way delay. SLAC™ device data sheets give the group delay data limits, the filter absolute delay limits, and the switch delay limits can be calculated from the switch design and the SLAC data sheet. The one way delay is 600–700 µs without the switch network delays. The minimum roundtrip delay is 1.2 ms and higher.

Figure 3. Frequency Response Graph with 10 dB Transhybrid Loss



RIPPLE AMPLITUDE

Table 1 shows the theoretical ripple for different transhybrid losses. Good line circuits have transhybrid losses greater than 25 dB for test conditions. Circuits terminated by a telephone-like device have much poorer transhybrid losses, typically 6–10 dB. Accurately measuring the amplitude ripple in the end-to-end frequency response provides a good estimate of the achieved transhybrid loss.

Table 1 Peak Ripple vs. Transhybrid Loss (THL)

dB THL	30	25	20	15	14	13	12	11	10	9	8	7	6
Ripple dB	.008	.025	.08	.25	.32	.40	.50	.62	.80	1.0	1.25	1.50	1.75

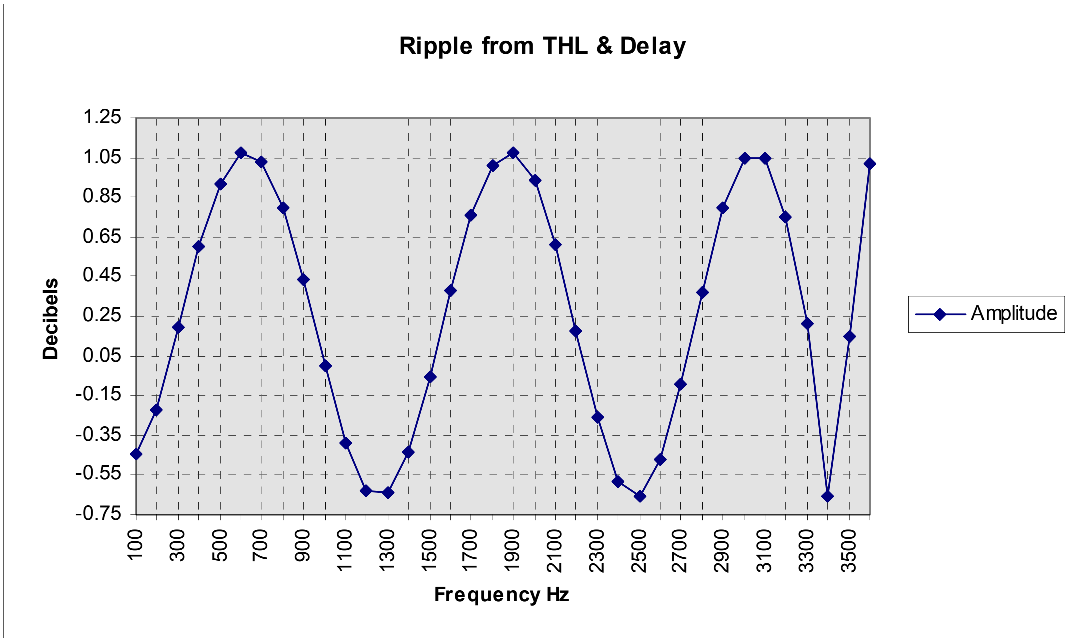
Table 1 assumes that both ends have equal transhybrid loss. Approximately the same results occur if the sum of the transhybrid losses equals two times the value that is for one end only.

The graphs shown in Figure 2 and Figure 3 assume that the encode filter and decode filter are essentially flat. Zarlink SLAC devices using coefficients calculated by WinSLAC™ generally have very small variations in their encode and decode filter frequency response. These typically small variations do not significantly change the appearance of data taken on these devices from that shown in Figures 2 and 3.

DIFFERENT ROUNDTRIP DELAY

The graphs shown in Figure 2 and Figure 3 are generated with a 1.25 ms roundtrip delay or a one way delay of 625 µs (measured from the QSLAC™ or DSLAC™ device). Actual digital switching circuits add additional delay. Each time slot interchange stage adds at least one frame or 125 µs of delay in each direction. Space switching stages add some number of bits to each one way delay. Figure 4 shows a graph made with twice the roundtrip delay, or 2.5 ms.

Figure 4. Higher Roundtrip Delay Graph



MATHEMATICS BEHIND THE RIPPLE

The sine wave traveling from the sending end to the receiving end is attenuated by the insertion loss of the encode and decode ends and their frequency response. Many line circuits set the insertion loss to unity gain or 0 dB. The ripple is caused by the delayed signal reenforcing or partially canceling the sending signal. Less cycles of ripple occur when the delays or phase shifts are small. Less ripple amplitude occurs when the transhybrid loss is large limiting the signal which causes the cancellation or re-enforcement.

Assume that the sending signal is a sine wave: A • sin(2 • π • F). The echo signal causing the ripple is attenuated by the sum of transhybrid loss of the receive end and the send end. This signal is delayed by time (RT_delay in Table 2), which is the roundtrip delay. This time delay corresponds to a phase shift of F • T radians. So the encoded signal becomes: A • sin(2 • π • F) + (THLa • THLb • A) • sin(2 • π • F + (F • T)). To increase the accuracy, add in twice the group delay for the various frequencies (once for each direction). Table 2 is a sample spreadsheet.

The roundtrip delay in seconds is calculated on paper from data sheets and design and filled in. The transhybrid loss, or THL, is entered as gain dB; i.e., a negative number and converted to a fractional loss number, Loss_a or Loss_b. The frequency column is a table fill covering the frequency range of interest. The total loss number is the product of Loss_a and Loss_b. The column of radian phase shift is calculated from the product of frequency and time delay.

The sine term is the sine of π/2 plus twice the phase shift of the group delay plus the phase shift column. The sine of PI/2 is one. So the composite column is 1 – (sine term column • total loss). This column converted to decibels by 20 • LOG(X) produces the data to be graphed. Convert the dB numbers to dB relative to the dB value for 1 kHz. Table 2 shows the format of the speadsheet. The spreadsheet does not show the relative dB column.

INTERPRETING A GRAPH

The graph's peak-to-peak ripple in Figure 3 is 1.65 dB. Thus the peak ripple is 0.8 corresponding to 10 dB transhybrid loss on each end or 20 dB total between the two ends. Figure 2 has the same peak ripple or the same transhybrid loss. The roundtrip delay is calculated by noting the frequency of peaks and adjacent valleys. Use the following formula to solve for the approximate round trip delay: π = (2 • F_H) – (2 • F_L), where F_H is the high frequency and F_L is the low frequency. If the data used is read accurately, the result is within 10% of the correct delay. Table 2, shows a simple way of creating graphs to compare circuit data.

Table 2 Sample Spreadsheet Calculation

RT_delay (.0025 s Rdtrip) Freq (Hz)	Radians Phase	THL_a (–10 dB) sine term	THL_b (–10 dB) composite (amp)	dB_Amp	Loss_a (0.316228) 0.1 s grp delay	Loss_b (0.316228) total loss
100	0.5	0.764842	0.923516	–0.69111	0.001	
200	1	0.530166	0.946983	–0.47315	0.00006	
300	1.5	0.068343	0.993166	–0.05957	0.000008	
400	2	–0.41796	1.041796	0.355658	0.000005	
500	2.5	–0.80204	1.080204	0.670116	0.000003	
600	3	–0.99016	1.099016	0.820081	0.000002	
700	3.5	–0.93621	1.093621	0.777338	0.000001	
800	4	–0.65364	1.065364	0.549963	0	
900	4.5	–0.2108	1.02108	0.181192	0	
1000	5	0.283662	0.971634	–0.24995	0	
1100	5.5	0.70867	0.929133	–0.63844	0	
1200	6	0.96017	0.903983	–0.8768	0	
1300	6.5	0.976588	0.902341	–0.89258	0	
1400	7	0.753902	0.92461	–0.68083	0	
1500	7.5	0.346635	0.965336	–0.30643	0	
1600	8	–0.1455	1.01455	0.125469	0	
1700	8.5	–0.60201	1.060201	0.507766	0	
1800	9	–0.91113	1.091113	0.757395	0	
1900	9.5	–0.99641	1.099641	0.825021	0.000005	
2000	10	–0.82238	1.082238	0.686452	0.000015	
2100	10.5	–0.42872	1.042872	0.364619	0.000025	
2200	11	0.081336	0.991866	–0.07094	0.000035	
2300	11.5	0.571166	0.942883	–0.51084	0.000045	
2400	12	0.91212	0.908788	–0.83075	0.00006	
2500	12.5	0.994106	0.900589	–0.90946	0.00007	
2600	13	0.801122	0.919888	–0.7253	0.00008	
2700	13.5	0.384039	0.961596	–0.34015	0.00009	
2800	14	–0.14235	1.014235	0.12277	0.0001	
2900	14.5	–0.65247	1.065247	0.549003	0.00012	
3000	15	–0.95882	1.095882	0.795279	0.00014	
3100	15.5	–0.9588	1.09588	0.795263	0.00016	
3200	16	–0.5962	1.05962	0.503003	0.0002	
3300	16.5	0.046224	0.995378	–0.04024	0.00025	
3400	17	0.988837	0.901116	–0.90438	0.0005	
3500	17.5	0.120062	0.987994	–0.10492	0.0008	
3600	18	–0.92447	1.092447	0.768009	0.001	

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