

White Paper on Sage’s G.168 Test Suite

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1 Introduction

ITU-T recommendation G.168 [1] (titled “Digital network echo cancellers”) defines a suite of objective tests that will ensure the minimum level of performance of an echo canceller when installed in the network. These tests are applicable to echo cancellers using digital signal processing techniques.

A total of 21 tests are specified in G.168/2000 [1]. Sage has implemented the first 15 of them (from test No.1 to test No. 10B). The last 6 tests are still under study by ITU.

This paper shows you how to conduct the G.168 tests using Sage’s test equipment. By doing so, this paper also briefly illustrates how these tests are implemented. This paper does not intend to replace the original ITU-T G.168 document [1]. Instead, this paper should be used in conjunction with the ITU G.168 document, as this paper makes frequent references to the G.168 document.

In the following sections, we first examine the general test principles, test configuration and test signals. After which, each specific test is then discussed in detail.

2 Test Configuration, Principles and Signals

2.1 Test configuration

The test configuration is shown in Figure 1.

As shown in Figure 1, the echo canceller under test sits “between” two Sage’s test instruments. The drop side of the echo canceller is connected to Sage’s Echo Generator [2]. This Echo Generator not only generates upto 2 echoes with selectable echo levels and echo delays, it can also mix in Hoth noise [3] and double-talk CSS [1] signal into the echo path to facilitate double-talk tests. The line side of the echo canceller is connected to a Sage equipment with G.168 test suite installed (we call it G.168 tester from here on). The connections are all digital T1/E1 with G.711 μ -law or A-law companding.

2.2 General principles

In reference to Figure 1, the goal of the echo canceller is to use the input signal R_{in} as a reference to cancel the echo signal S_{in} if the two signals are linearly correlated (true echoes). An echo canceller

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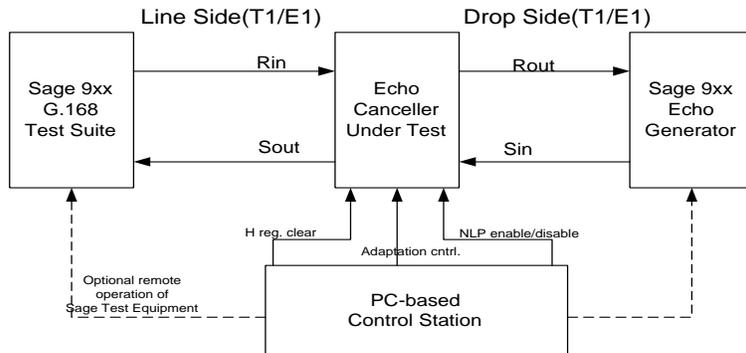


Figure 1: G.168 test configuration.

should not introduce any level change (loss or gain) between R_{in} and R_{out} , but it should make S_{out} much less (in level) than S_{in} if S_{in} is indeed an echo of R_{in} .

During a test, the test equipment at left (G.168 tester) will generate various test signals and send them to the echo canceler as R_{in} . Under user's control, it then measures the returned signal (residual echo) S_{out} at the receiving path. The equipment at right is an Echo Generator. Its function is to simulate an echo path by echoing the incoming signal R_{out} back as S_{in} with selectable attenuation and delay, plus the capability of mixing in Hoth noise and double-talk CSS into the echo path. If possible, a separate PC is also needed to control the echo canceler for such purposes as clearing the H-register, inhibiting/enabling the adaptation and turning on/off the NLP (Non-Linear-Processor) etc.

2.3 Test signals

The G.168 tester (the left side in Figure 1) generates and measures the following test signals:

1. Single-talk CSS: Composite-Source-Signal. This is the signal used in most of the tests. In time-domain, it consists of 3 portions, the active voice portion, the random noise portion and the silence (pause) portion. A snapshot of the signal is shown in Figure 2. The exact duration, power-spectral-density and peak-to-RMS ratio characteristics are specified in ANNEX C of G.168 [1].
2. Narrow-band signals. These are various signal-tone or dual-tone signals. Their frequencies are either related to DTMF digits (combinations of 697Hz, 770Hz, 852Hz, 941Hz, 1209Hz, 1336Hz, 1477Hz and 1633Hz), or related to the ITU-T No. 5, 6 and 7 in-band signalling tones (1780Hz, 2000Hz, 2400Hz and 2600Hz) and the 1100Hz tone and 2100 Hz tone.
3. Fax modem signal. This is the fax modem phase-continuous FSK signal. The center frequency is 1750Hz, frequency deviation is 100Hz and signalling rate is 300 symbols/s.

The Echo Generator side (right side in Figure 1) not only echoes back the signal R_{out} with selected level and delay, it also mixes in the following signals during the double talk and convergence tests:

1. Double-talk CSS. This double-talk composite source signal sounds similar to the single-talk CSS, but technically they are different (non-correlated). It still consists of active voice portion,

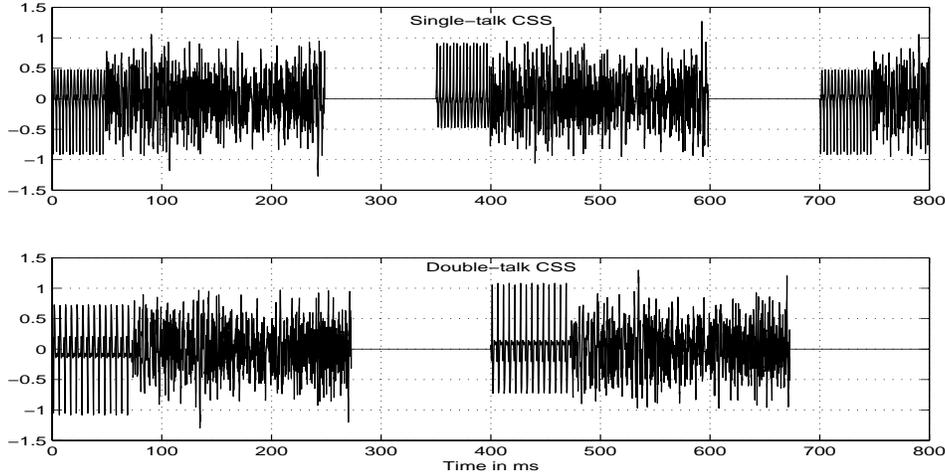


Figure 2: Snapshots of signal-talk and double-talk Composite-Source-Signal used in G.168 tests.

noise portion and the silence portion. But the details of the active voice signal and noise signal are different from those of the single talk CSS, and the duration of each portion is also different. A snapshot of the double-talk CSS is shown in Figure 2. Detailed specifications of the signal are in ANNEX C of G.168 [1].

2. Hoth noise. This is a spectrally-shaped continuous noise signal. Its power-spectral-density is specified in P.800 [3].

3 Detailed Test Procedures

This section presents detailed operation procedures on each of the G.168 tests that have been implemented on Sage’s test equipment.

3.1 Common operation procedures

All of the 15 tests that will be detailed below require the following common operation procedures:

1. Connect all the equipment as shown in Figure 1 and verify audio signal path by sending-tone and measuring-tone on both directions. There should be no level change between R_{in} and R_{out} . Neither should there be any level difference between S_{in} and S_{out} . **WARNING:** do not send tones on both directions simultaneously, as this may trigger the echo canceller into “false” cancellation mode, hence affecting the measurement on the S_{in} to S_{out} direction.
2. Put the drop-side Sage equipment in the Echo Generator mode (option 84 on 93x) and select the proper echo level(s) and echo delay(s).
3. Put the line-side Sage equipment in the G.168 test mode (option 68) and select the desired test number and test signal level.

4. Control the echo canceller’s internal components such as clearing the H-register, inhibiting/enabling adaptation and enabling/disabling the NLP etc, according to the G.168 requirements.
5. Press “START” button on the G.168 tester side. The clock should start ticking, and in most cases, one will hear some test signal.
6. After a certain period (specified in G.168 and indicated by the clock ticking), press the “MEASURE” button, and the actual measurement will take place. The results will be displayed once the measurement is done.

3.2 Important note: test numbering and echo level representation

For convenience and clarity, the same test numbering used in G.168 document [1] has been used in Sage’s G.168 tester. For example, if one wants to perform Test No. 2A in G.168 document [1], one just selects test 2A from Sage’s G.168 tester.

Most of the test results are related to the residual echo level, that is, the power level of signal S_{out} . For probably historical reasons, there are two different (and potentially confusing) ways of representing the residual echo level: one as absolute power level in dBm, and the other as relative ERL (Echo-Return-Loss) in dB. For example, assume the test signal level (R_{in} level) is set at -10 dBm, and the residual echo level (S_{out} level) is -50 dBm, then the residual echo level can also be represented as an ERL of 40 dB. Per G.168 specifications, in different tests, different representations are used for the results. If one sees a positive number with dB unit, then the result should be interpreted as ERL. If one sees a negative number with dBm unit, then the result should be interpreted as absolute power level.

The same confusion also applies to the Echo Generator. Sage’s Echo Generator designates echo level as a relative level in reference to the incoming signal. For example, if Echo Generator is set to generate an echo of -10 dB, that means, the S_{in} signal is 10 dB lower in level than the signal R_{out} in Figure 1. On the G.168 document, however, the echo level is expressed in ERL. Simply put, an ERL of 10 dB is the same as an echo level -10 dB. To generate an echo with $ERL > 10$ dB means setting up an echo on Echo Generator with level less than -10 dB. The “echo path delay” on G.168 means the same thing as echo delay on the Echo Generator.

3.3 Test No. 1, Steady state residual and returned echo level test

This test is specified in G.168/1997. But in G.168/2000 [1], this test has been merged into test 2. Sage kept this test, in case a user only wants the steady-state measurement, instead of the whole transient convergence profile.

The goal of this test is to determine the steady-state cancellation depth of an echo canceller. Figure 3 shows the timing and signal relationships. The operation procedures are:

1. Connect the equipment and verify audio paths.
2. Clear the echo canceller H register and inhibit adaptation (optional).
3. Enable or disable the echo canceller NLP (both cases need to be tested).

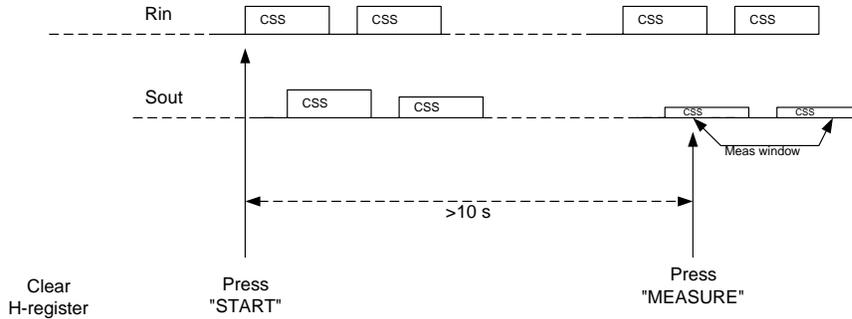


Figure 3: Test No. 1 signal and timing relationships.

4. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
5. On the G.168 tester side, select test No. 1, and set proper test signal level per G.168 requirement.
6. Enable echo canceller adaptation (optional).
7. Press G.168 tester “START” button, the CSS test signal is now being sent out, and the clock ticking should also be displayed.
8. After a while (>10s), press ”MEASURE”, and the measurement will take place. The result will be available within 1 second. As shown in Figure 3, the measurement window size is 350 ms, equal to the period of the single-talk CSS signal.
9. The measurement result is absolute residual echo level (S_{out} level) in dBm. There is only one result for this test.

3.4 Test No. 2, Convergence and Steady state residual and returned echo level tests

The goal of this “suite” of tests is to ensure that the echo canceller converges rapidly for all combinations of input signal levels, echo paths, and certain echo path changes, and that the returned echo level is sufficiently low. Test No. 2 actually involves the following 3 tests.

3.4.1 Test No. 2A, Convergence test with NLP enabled

This test is to determine the convergence profile and the steady-state cancellation depth of an echo canceller with NLP (Non-Linear-Processor) on. The test timing and signal relationships is shown in Figure 4.

The test procedures are as follows:

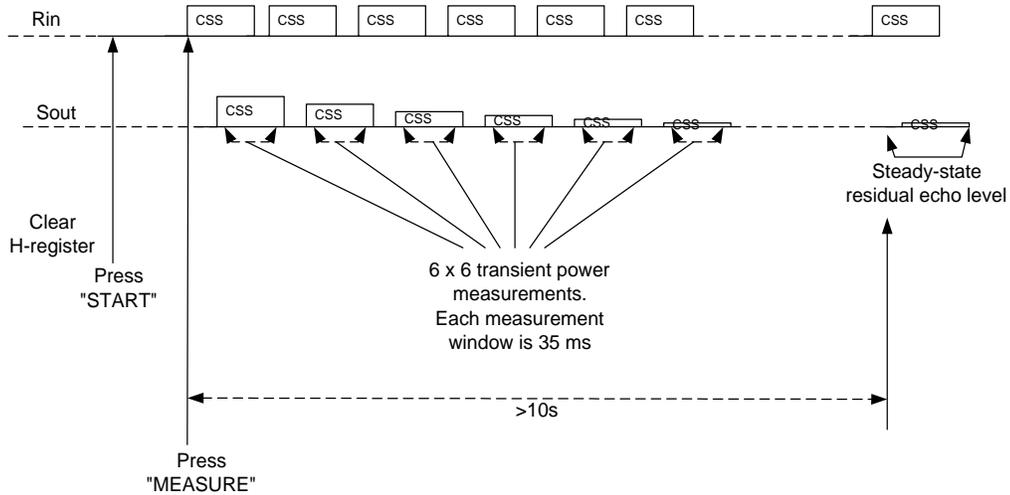


Figure 4: Test No. 2A and 2B signal and timing relationships.

1. Connect the equipment and verify audio paths.
2. Clear the echo canceller H register and inhibit adaptation (optional).
3. Enable echo canceller NLP.
4. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
5. On the G.168 tester side, select test No. 2A, and select proper test signal level per G.168 requirement.
6. Press “START” button, the circuit remains quiet but the clock should start ticking.
7. Enable echo canceller adaptation (optional).
8. After a while ($>0.2s$), press ”MEASURE”. One should hear the single-talk CSS signal and the measurement will also take place. The results will be available in about 10 seconds. As shown in Figure 4, there are two groups of measurements. The first group of measurements captures the transient echo level profile by measuring the “instantaneous” power levels of the active portions of the first six CSS signal bursts. The silence portion of CSS signal is skipped over per G.168 requirement. Within the active portion (active voice and noise portions) of each CSS burst, six “instantaneous” power levels are measured. The window size of each measurement is 35 ms, per G.168 requirement. The total time span covered by these 36 measurements is $36 \times 35 = 1260ms$, but the actual time elapsed (including the skipped silence portion) is $6 \times 350 = 2100ms$. The second group of measurement determines the steady-state residual echo level and takes place about 10 seconds later. The second group of measurement is identical to that of Test No. 1, except the result is represented as ERL in dB, instead of absolute level in dBm.

9. There are a total of 37 measurement results representing the residual echo level as ERLs in dB. The first 36 results are the convergence profile, measured in steps of 35 ms and a window size of 35 ms. The profile covers the active portions of the first 6 CSS bursts. The last measurement result is the steady-state echo level represented as ERL in dB (measured 10 s later).

3.4.2 Test No. 2B: Convergence test with NLP disabled

The test procedures and results are identical to those of test 2A, except the NLP should be disabled, and test 2B should be selected on the G.168 tester.

3.4.3 Test No. 2C: Convergence test in the presence of background noise

This test is ensure that the steady-state cancellation depth is not affected by the presence of background noise in the echo path. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Clear the echo canceller H register and inhibit adaptation (optional).
3. Enable or disable the echo canceller NLP (both cases need to be tested).
4. On the Echo Generator side, select proper echo level and delay per G.168 requirement, and also turn on the Hoth noise with proper level.
5. On the G.168 tester side, select test No. 2C, and select proper test signal level per G.168 requirement.
6. Enable echo canceller adaptation (optional).
7. Press the G.168 tester “START” button, the CSS test signal is now being sent out, and the clock ticking should also start.
8. After a certain period (see G.168 for specific number), turn off Hoth noise on the Echo Generator side, inhibit the adaptation (optional), and press “MEASURE” on the G.168 tester side. The measurement should be done in 1 second.
9. The measurement result is absolute residual echo level (S_{out} level) in dBm. There is only one result for this test.

3.5 Test No. 3, Performance under conditions of double talk

The goal of this “suite” of tests is to determine the echo canceller performance under various conditions of double talk. Test No. 3 includes the following 3 tests.

3.5.1 Test No. 3A: Double talk test with low cancelled-end levels

This test is to ensure the echo canceller's double talk detection is not so sensitive to low-level near-end speech as to impact the normal adaptation. Please refer to Figure 17 of G.168/2000 [1] for the detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Clear the echo canceller H register and inhibit adaptation (optional).
3. Disable the echo canceller NLP and enable adaptation.
4. On the Echo Generator side, select proper echo level and delay per G.168 requirement, and also turn on the double-talk CSS with proper level (should be low-level).
5. On the G.168 tester side, select test No. 3A, and select proper test signal level per G.168 requirement.
6. Enable echo canceller adaptation (optional).
7. Press the G.168 tester "START" button, the CSS test signal is now being sent out, and the clock ticking should also start.
8. After a certain period (5 s per G.168), turn off the double-talk CSS on the Echo Generator side, inhibit the adaptation (optional), and press "MEASURE" on the G.168 tester side. The measurement should be done in 1 second.
9. The measurement result is absolute residual echo level (S_{out} level) in dBm. There is only one result for this test.

3.5.2 Test No. 3B: Double talk test with high cancelled-end levels

This test is ensure the echo canceller's double talk detection is sensitive enough and operates fast enough to prevent large divergence during double talking. Please refer to Figure 18 of G.168/2000 [1] for the detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Disable the echo canceller NLP and enable adaptation.
3. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
4. On the G.168 tester side, select test No. 3B, and select proper test signal level per G.168 requirement.
5. Press the G.168 tester "START" button, the CSS test signal is now being sent out, and the clock ticking should also start.
6. After a certain period (>5 s), turn on the double-talk CSS on the Echo Generator side. The double-talk CSS level should be higher than the G.168 tester side single-talk CSS level.

7. After an arbitrary duration (see G.168 for guidance), inhibit the adaptation (optional), remove the double-talk CSS on Echo Generator side and press “MEASURE” on the G.168 tester side. The measurement should be done in 1 second.
8. The measurement result is absolute residual echo level (S_{out} level) in dBm. There is only one result for this test.

3.5.3 Test No. 3C: Double talk test under simulated conversation

This test is ensure the echo canceller does not produce undesirable artifacts during and after periods of double talk. Please refer to Figure 19 of G.168/2000 [1] for the detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Clear echo canceller H-register, enable NLP and adaptation.
3. On the Echo Generator side, select proper echo level and delay per G.168 requirement. Program the double-talk CSS level to be higher than the single-talk CSS, but do not turn it on yet.
4. On the G.168 tester side, select test No. 3C, and select proper test signal level per G.168 requirement.
5. Press the G.168 tester “START” button, and meanwhile, turn on the double-talk CSS at the Echo Generator side.
6. After a certain period ($>5.6s$ per G.168), turn off the double-talk CSS at Echo Generator side, and press “MEASURE” at the G.168 tester side.
7. After another period ($>5.4s$ per G.168), turn on the double-talk CSS on the Echo Generator side again, and press “MEASURE” at the G.168 tester side again.
8. After yet another period ($>5.6s$, per G.168), press “MEASURE” one more time at the G.168 tester side, and the measurement should be done in 1 second.
9. The measurement results are absolute residual echo levels (S_{out} level) in dBm. There are four results. Results 1, 3 and 4 are residual peak levels in periods of t_2 , t_4 and t_5 in Figure 19 of G.168/2000 [1]. Result 2 is the steady-state residual echo level in period t_3 in Figure 19 of G.168/2000 [1].
10. Notice that, in this test, you have to press the “MEASURE” button 3 times altogether.

3.6 Test No. 4: Leak rate test

This test is to ensure that the leak time is not too fast, i.e., the contents of the H-register do not go to zeroes too rapidly. Please refer to Figure 20 of G.168/2000 [1] for the detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.

2. Disable echo canceller NLP and and enable adaptation.
3. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
4. On the G.168 tester side, select test 4 with proper signal level, and press “START”. The CSS signal should be sent out and clock should start ticking.
5. After a certain period (about 10s), press “MEASURE”. The circuit will be quiet. After 2 minutes, the CSS signal will be sent again and measurement will be performed.
6. If possible (optional), 2 minutes after pressing “START”, the echo canceller H-register contents should be frozen.
7. The measurement result is residual echo level in dBm. There is only one result for this test.

3.7 Test No. 5: Infinite return loss convergence test

This test is to ensure that the echo canceller has some means to prevent the unwanted generation of echoes. Please refer to Figure 21 of G.168/2000 [1] for the detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Disable echo canceller NLP and and enable adaptation.
3. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
4. On the G.168 tester side, select test 5 with proper signal level, and press “START”. The CSS signal should be sent out and clock should start ticking.
5. After a certain period (about 10s), turn off the echo at the Echo Generator side, and meanwhile, press “MEASURE” at the G.168 tester side. The measurement will be done in about 2 seconds.
6. The measurement results are 36 transient power level profile of potential “phantom echoes” caused by the echo canceller after the echo path has been turned off. The 36 results are consecutive transient power level measured with a window size of 35 ms and in step of 35 ms. The results are represented as ERLs in dB.

3.8 Test No. 6: Non-divergence on narrow-band signals

This test is to ensure that the echo canceller will remain converged for subscriber-originated narrow-band signals after having converged on a wide-band signal. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Disable echo canceller NLP and and enable adaptation.
3. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
4. On the G.168 tester side, select test 6 with proper signal level, and press “START”. The CSS signal should be sent out and clock should start ticking.

5. After a certain period (about 10s), press “MEASURE” at the G.168 tester side. A sequence of DTMF-like single and dual-tone signals will be sent for 5 s. After which, CSS signal will be re-applied and measurement will be performed.
6. The measurement result is the residual echo level in dBm. There is only one result for this test.

3.9 Test No. 7, Stability test

This test is to ensure that the echo canceller will remain stable for narrow-band signals. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Clear H-register, disable NLP and enable adaptation.
3. On the Echo Generator side, select proper echo level and delay per G.168 requirement.
4. On the G.168 tester side, select test 7 with proper signal level, and press “START”. A narrow-band tone signal (1010Hz) will be sent out and the clock should start ticking.
5. After a certain period (about 2 minutes, per G.168), press “MEASURE”, and measurement will be done in 1 second.
6. The measurement result is the residual echo level in dBm. There is only one result for this test.

3.10 Test No. 8: Non-convergence on No. 5, 6 and 7 in-band signalling

This test is only optional per G.168. So it is not implemented in the G.168 tester *per se*. But if this test is needed, one can use the basic Sage test equipment’s sending-tone and measuring-tone functions to perform this test. For detailed procedures, please refer to section 6.4.2.8 of G.168/2000 [1].

3.11 Test No. 9: Comfort noise test

This test is to ensure that the echo canceller is able to provide a comfort noise signal on S_{out} that matches noise received on S_{in} . The test procedures are:

1. Connect the equipment and verify audio paths.
2. Enable echo canceller’s NLP and comfort noise feature, and also enable adaptation.
3. On the Echo Generator side, select proper echo level (-8 dB per G.168) and delay per G.168 requirement, and turn on the Hoth noise source. The Hoth noise level is set at different levels in different parts of the test. See the description of signal N in section 6.4.2.9 of G.168 [1].
4. On the G.168 tester side, select test 9 with proper signal level (-10 dBm), and press “START”. A low-level white noise (-62 dBm) will be sent out and the clock should start ticking.

5. After a certain period (about 30 s per G.168), press “MEASURE”. A loud white noise (-10 dBm) will be sent for 2 seconds and measurement will be performed afterwards.
6. The measurement result is the residual echo noise level in dBm. There is only one result for this test.

3.12 Test No. 10: Fax test during call establishment phase

This test is to ensure that the echo cancellers located at each end of a connection converge rapidly on the initial handshaking sequences of a fax call and have some means to prevent generation of unwanted echoes. This test involves the following two parts.

3.12.1 Test No. 10A: Canceller operation on the calling station side

Please refer to Figure 23 of G.168/2000 [1] for detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Clear H-register and enable adaptation. NLP should be enabled or disabled (both cases need to be tested).
3. At the Echo Generator side, leave the Echo Generator mode and go to sending-tone mode. Send a tone of 1100Hz, -13 dBm for 500 ms. Then go back to the Echo Generator mode. This step is only optional. It has no effect on the actual measurements.
4. Set up the Echo Generator with proper echo level and echo delay.
5. At the G.168 tester side, select test No. 10A and set the signal level to -13 dBm. Press “START”, the circuit should be quiet and the clock should start ticking.
6. After a while (< 2.55 s), press “MEASURE”, a sequence of Fax-modem signals (2100Hz tone followed by the FSK signal) will be sent for about 10 seconds, and measurements also take place simultaneously.
7. The measurement results indicate the convergence profile of the returned echo as shown in Figure 23 of G.168/2000 [1]. More specifically, there are 6 results. The 6 results, in order, represent the following parameters in reference to Figure 23 of G.168/2000 [1]: peak level (dBm) in region I, duration (s) of region I, peak level (dBm) in region II, peak level (dBm) of region III, duration (s) of region III and peak level (dBm) of region IV.

3.12.2 Test No. 10B: Canceller operation on the called station side

Please refer to Figure 24 of G.168/2000 [1] for detailed timing and signal relationships. The test procedures are:

1. Connect the equipment and verify audio paths.
2. Clear H-register and enable adaptation. NLP should be enabled or disabled (both cases need to be tested).

3. Set up the Echo Generator with proper echo level and echo delay.
4. At the G.168 tester side, select test No. 10B and set the signal level to -13 dBm. Press “START”, the circuit should be quiet and the clock should start ticking.
5. After a while (> 200 ms), press “MEASURE”, a sequence of Fax-modem signal (FSK signal) will be sent for about 10 seconds, and measurements also take place simultaneously.
6. The measurement results indicate the convergence profile of the returned echo as shown in Figure 24 of G.168/2000 [1]. More specifically, there are 3 results. The 3 results, in order, represent the following parameters in reference to Figure 24 of G.168/2000 [1]: peak level (dBm) in region I, duration (s) of region I, and peak level (dBm) in region II.

References

- [1] “Digital network echo cancellers,” *ITU-T Recommendation G.168*, April 2000.
- [2] Renshou Dai, “White paper on Sage’s Echo Sounder and Echo Generator,” Sage Instruments White Paper series.
- [3] “Methods for subjective determination of transmission quality,” *ITU-T Recommendation P.8000*, 1996.