Testing CAS Detector Performance with the AI 240

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Introduction

All CPE's that provide the capability to handle Type II Caller ID messages, also termed as Caller ID on Call Waiting, require a CAS tone detector. The detector's purpose is the proper recognition of the CAS tone in the possible presence of voice or other signals. The ability of this detector to reliably detect the CAS tones is key to the proper operation of the CPE. Missed CAS tones will mean that the CPE will not receive the Caller ID message destined to it. And possibly more serious, falsely detected CAS tones will cause the CPE to mute for approximately half a second. This can be very annoying to the user of the CPE and will be perceived as poor product quality.

As such Bellcore has outlined a procedure for testing a CPE's CAS detector performance, along with performance recommendations. This application note describes the steps for implementing these tests with the AI 240 CAS Test System. The basis for these procedures are the Bellcore SR-TSV-002476 and SR-3004 documents. At the time of this writing, it is known that the Bellcore documents will be updated in the near future. As such it is strongly recommended that users of these procedures be aware of possible changes to the recommendations by Bellcore. Note that the recommendations and procedures in the above mentioned Bellcore can be subject to different interpretations. Therefore the procedures outlined in this application note can only reflect the author's best interpretation.

There are three basic categories of tests performed on the CAS detector. These are:

i) signal recognition tests,
ii) talk-off tests, and
iii) talk-down tests.

The signal recognition tests determine the immunity of the CAS detector to variations in the CAS tone characteristics. These variations are possible due to the different loop lengths the CPE will experience, along with the differences in the CO's CAS tone generator. The talk-off tests are used to find out how immune the CAS detector is to falsely recognizing speech signals as CAS tones. This is performed from the perspective of both near-end speech and far-end speech. Finally, the talk-down test determines the ability of the detector to properly receive the CAS tone in the presence of interfering speech signals. This test is only performed with near-end speech, as the CO will mute the far-end speech before the CAS signal is sent.

The remainder of this application note describes the equipment and test setup needed along with procedures for performing each of the above mentioned test groups.

Equipment Required and Test Setup

One of the difficult aspects of performing the recommended tests is the complex test setup required. The AI 240 greatly simplifies this by combining most of the needed instruments together in a single piece of equipment, that operates in an integrated fashion under the Windows operating system. However, depending on the CPE design, additional equipment may be required for some of the tests. The CAS detector within the CPE can be designed to sense the signals directly from the tip and ring telephone interface, or from the receive port of the CPE's hybrid. The advantage of sensing the CAS signal from the hybrid receive port is that the near-end voice will be reduced in level by the amount of the trans-hybrid loss of the CPE. This reduction in near-end speech level makes it easier to meet the talk-down and near-end talk-off recommendations. However, for such a CPE, the test setup is more complex.

Two test setups are presented here that can be used to perform all of the tests with either type of CPE. These have been termed as 'setup A' and 'setup B'. Setup A is the simpler of the two configurations. If the CAS detector senses from tip and ring, then all of the tests can use this setup. The following table shows for a given test and CPE type, what needed setup is.

Test Name	CPE Type (CAS on tip and ring)	CPE Type (CAS on hybrid rx)
Signal Recognition	*Setup A*	*Setup A*
Talk-Down	*Setup A*	*Setup B*
Talk-Off (near end)	*Setup A*	*Setup B*
Talk-Off (far end)	*Setup A*	*Setup A*

Table 1

Test Setup A

Figure 1, shows the test setup A. Being the simpler of the two, it requires the least amount of additional equipment. It also has the advantage of being used most often.

The additional equipment needed is as follows:

- Speech source (DAT/CD player with the Bellcore tapes highly recommended)
- CPE under test

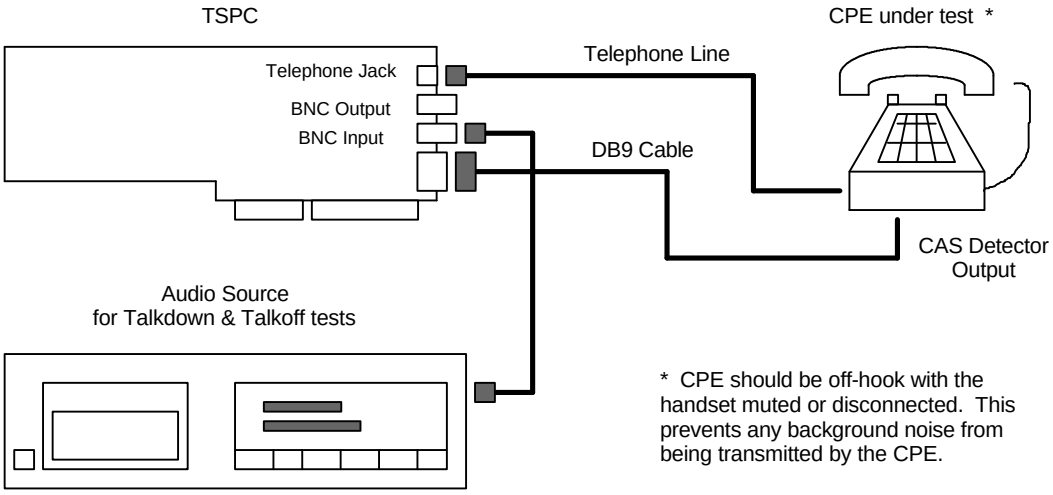


Figure 1: Test setup A

For this test setup, the audio source is connected to the BNC input connector on the TSPC card. A telephone cord connects the TSPC to the CPE under test via the RJ-11 connector. And finally, the CAS detect signal is fed back to the TSPC via the DB9 connector. Depending on the specific design of the CPE, the returning CAS detect signal can cause a grounding fault with the test setup. If such a condition occurs when the test setup is connected, the CAS2200 program will report an “Unbalanced” condition. This grounding fault can alter the signal levels generated and measured by the test setup, and as such must be resolved before proceeding with the tests. It may require that the CAS detect signal be isolated by means of an optoisolator, relay, or other. More information regarding the connection of the CPE to the TSPC can be found in the CAS2200 “User Guide & Reference Manual” under the section “Connecting the CPE”.

Test Setup B

Figure 2, shows the test setup B. This setup is required for the talk-down test and near-end talk-off test, only if the CPE senses the CAS signal from the hybrid receive port. Being a more complex than test setup A, additional equipment is required.

The additional equipment needed is as follows:

- Speech source (DAT/CD player with the Bellcore tapes highly recommended)
- Acoustic test head (provides mounting for handset and artificial mouth)
- Amplifier for the artificial mouth (if not provided with the test head)
- Telephone line test loops as described in SR-3004
- Differential telephone line amplifier
- CPE under test

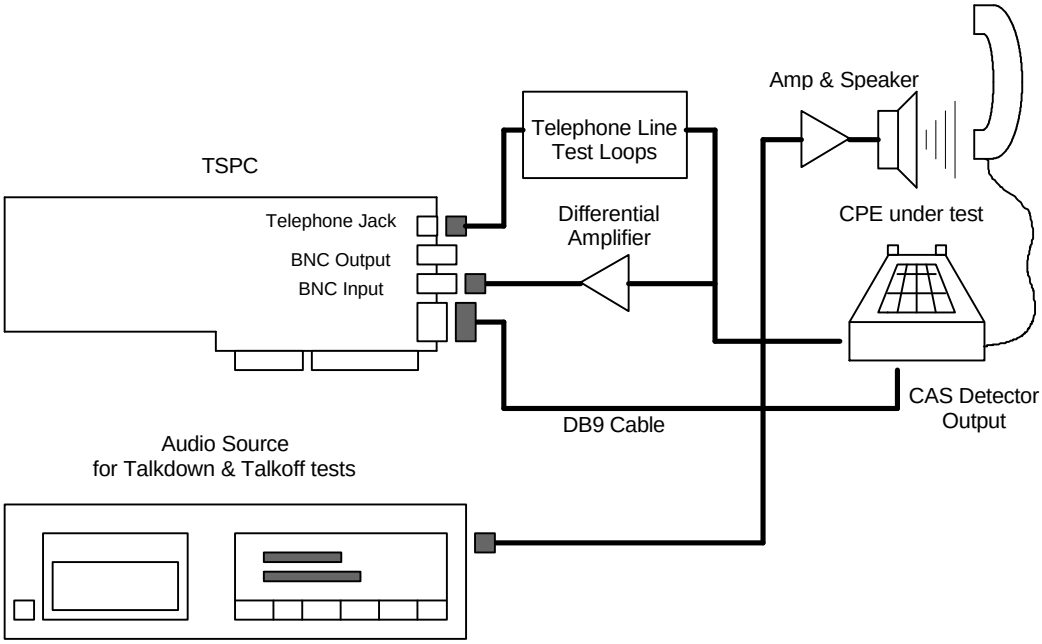


Figure 2: Test setup B

In this test setup, the speech signals are injected acoustically into the CPE's handset as opposed to being injected directly at the tip and ring interface. This is required to take advantage of the trans-hybrid loss offered by the CPE. Near-end speech is only used for the talk-down and near-end talk-off tests and as such, test setup B is only required for these two tests.

The audio source is connected directly to the acoustic test head. As most high quality DAT or CD players can provide a variable output level, this can be used to adjust the speech level. Also required in this test setup is the use of artificial line length segments. These segments are inserted in between the RJ-11 jack of the TSPC and the CPE under test. The specific segment configurations are shown in detail in the Bellcore document SR-3004 and are commercially available. All the signal levels are measured at tip and ring on the CPE side of the line lengths. As such a differential amplifier is used to convert the balanced signal to unbalanced, and then fed to the TSPC BNC input for measurement. The differential amplifier should have an input impedance of at least 100 kohms, such that the telephone line impedance is not greatly altered.

This test setup is more prone to inconsistent results if not performed carefully. The reason being the acoustic coupling used. A proper test head with artificial mouth is recommended to provide a flat and consistent frequency response. Also important is to minimize the background noise, as it can effect the test results. It is possible to electrically couple the speech signal directly to the CPE handset, just after the microphone. This will eliminate the need for an acoustic test head. However, this can effect the speech pre-emphasis needed for the near-end voice. It is possible to compensate for this electrically, but is outside the scope of this application note as it requires detailed knowledge of the CPE in question.

And finally, the CAS detect signal is fed back to the TSPC via the DB9 connector. Depending on the specific design of the CPE, the returning CAS detect signal can cause a grounding fault with the test setup. If such a condition occurs when the test setup is connected, the CAS2200 program will report an “Unbalanced” condition. This grounding fault can alter the signal levels generated and measured by the test setup, and as such must be resolved before proceeding with the tests. It may require that the CAS detect signal be isolated by means of an optoisolator, relay, or other. More information regarding the connection of the CPE to the TSPC can be found in the CAS2200 “User Guide & Reference Manual” under the section “Connecting the CPE”.

Measuring the Active Speech Level

For both the talk-down and talk-off tests, a source of speech is needed in order to determine how the CAS detector performs in the presence of speech. As such, it is reasonable to assume that the audio signal used should be as close as possible to actual telephone conversations. One of the best sources of such material are talk radio shows. These generally have little musical content with a wide variety of people speaking (at least half the time). Bellcore makes available a set of DAT tapes that contains over 96 hours of recorded talk radio shows. The tapes have also been processed to maintain a reasonably consistent long term speech level. This is important as the talk-down and talk-off tests should be run over a very long time for accurate results. So ensuring that the long term speech level of the source material is consistent becomes important. It is recommended that the Bellcore tapes be used for these tests for the above reasons and also since they provide a repeatable audio source that can be used over many times. These tapes can be purchased from Bellcore by citing the part number of LP-B17. At the time of this writing, Bellcore will be soon releasing the audio source in a CD format as well.

Regardless of what source of audio is used, the speech level must be determined in order to calculate the test results. As specified in SR-TSV-002476, speech levels are expressed as Active Speech Level (ASL) in units of dBm (600 ohm termination). The ASL is measured using the Method B of Recommendation P.56, published in the CCITT Blue Book, Volume V. The AI 240 includes a speech level meter that follows this measurement method. This ASL meter will be used to measure the speech levels of the audio source.

Measuring ASL for Test Setup A

The measuring of the ASL for test setup A is very straight forward. The audio source is injected in the BNC input connector of the TSPC. The CAS2200 program will pass this signal though the built in equalizer and out to the telephone line interface. It is at the telephone line interface that the speech level is measured. The signal routing matrix of the CAS2200 program should look as follows.

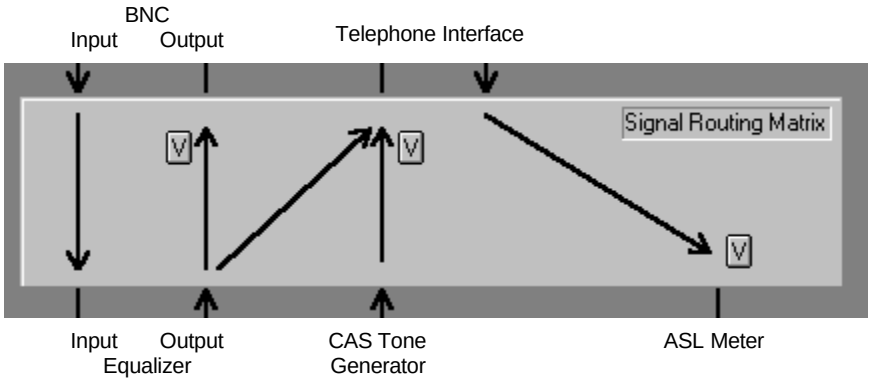
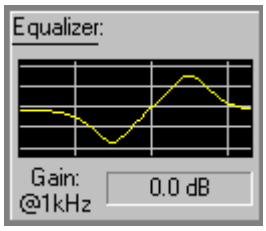


Figure 3: Signal Routing for Test Setup A

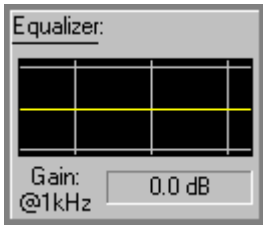
The ASL level should be measured before the talk-down and talk-off tests. Once each tape is measured, record the ASL as a reference for future use. For the talk-down and near-end talk-off

tests, the audio source must be pre-emphasized in order to simulate near-end voice. Bellcore recommends 5 dB of gain at 3 kHz relative to 1 kHz, and 5 dB of loss at 300 Hz relative to 1 kHz. The default settings of the equalizer will provide these levels. The equalizer panel in the CAS2200 program should look something like the following.



Measure each audio tape with pre-emphasis and the equalizer gain at 0 dB. Make sure the CAS tone generator is not active, as this will effect the ASL readings. It is important to note that the measurement must be done with the CPE disconnected from the telephone line, and a 600 ohm termination in its place. The ASL levels at the telephone line must be measured into 600 ohms for both the pre-emphasized and flat equalizer settings. This also has the advantage that the ASL measurements will be the same regardless of what CPE is tested. So once all the ASL measurements have been made, the levels can be used repeatedly in testing other CPE's. Once the ASL for each tape is known, then when performing the talk-down and near-end talk-off test, the desired ASL value can be set by adjusting only the gain of the equalizer. For example, if the measured ASL value was -12.8 dBm and the test requires a level of - 19 dBm, then set the equalizer gain to -19 - -12.8 = -6.2 dB.

For the far-end talk-off test, the audio source is not pre-emphasized. As such the audio tapes need to be measured again with the equalizer set to a flat response as shown below.



Once again, record the ASL level of each tape. Then similar to the talk-down and near-end talk-off tests, the desired ASL level can be set by adjusting only the gain of the equalizer. Since the ASL levels of each tape are now recorded, they do not need to be measured again.

Measuring ASL for Test Setup B

The ASL is measured for setup B in a different manner than for setup A. Because of the telephone test loops situated between the TSPC's telephone interface and the CPE under test, the ASL can not be measured at the TSPC's telephone interface. The signal at the CPE tip and ring leads is sensed by the differential amplifier and routed to the BNC input of the TSPC. It then passes through the equalizer and is measured by the ASL meter. The signal routing matrix of the CAS2200 program should look as follows.

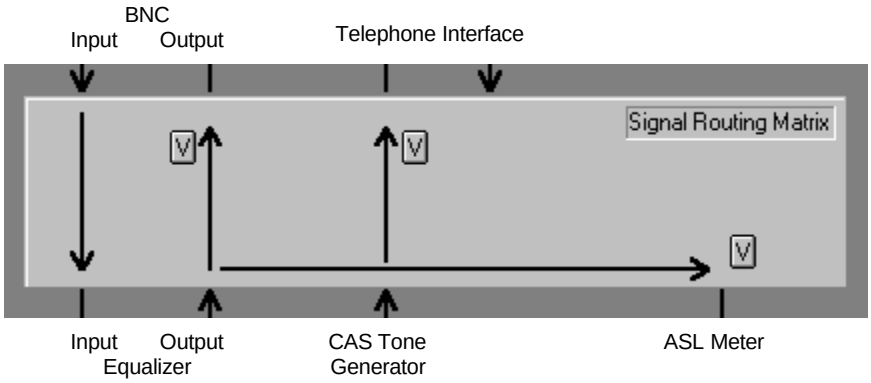


Figure 4: Signal Routing for Test Setup B

The equalizer should have a flat response, while its gain setting can be used to offset any gain or loss through the differential amplifier. To measure the audio source, the audio signal is acoustically coupled to the CPE's handset. This signal is then transmitted to the tip and ring leads at the CPE. At this point the differential amplifier will pick up the audio signal and route it to the TSPC for measurement. If an accurate programmable audio attenuator is available, then insert it between the DAT/CD player and the artificial mouth. Then, like for test setup A, the ASL needs to measured only once. Once the ASL value for each tape is known, then when performing the talk-down and near-end talk-off tests, the desired ASL value can be set by adjusting the level of the programmable attenuator. As with test setup A, the CAS tone generator must not be active during the measurement, as it will effect the ASL readings.

Note that when measuring the ASL level with the CPE in the off-hook state, it is possible for a talk-off event to occur, in which the CPE falsely recognizes a CAS tone and proceeds to generate the required ACK tone. Such an ACK tone will effect the ASL readings. Therefore it is important that the CPE not respond with ACK tones at any time during the ASL measurement.

Measuring the Trans-Hybrid Loss for Test Setup B

The telephone test loops should be set to a configuration that yields the minimum trans-hybrid loss of the CPE before performing any talk-down or talk-off tests. Using a worst case test loop ensures that the results of the talk-down/talk-off testing will be conservative. A detailed procedure for determining the worst case test loop is outlined in Bellcore's SR-3004 document. This procedure will not be repeated here, but it involves testing each of the recommended test loops one at a time in order to determine the loop that yields the lowest trans-hybrid loss. When performing this procedure, it is important to also measure the trans-hybrid loss with no test loop. This is the condition of the CPE directly connected to the TSPC. It is quite possible that this configuration results in the worst trans-hybrid loss. If this is the case, then the differential amplifier is not needed, and the signals at the tip and ring interface can be measured directly by the TSPC..

Setting up the CAS2200 Data Logger

In order for the CAS2200 program to properly detect the CAS pulses generated by the CPE, the Data Logger must know the characteristics of pulse generated by the CPE. Depending on the implementation of the CAS detector within the CPE, the actual CAS detect signal may not be available as a signal to probe. In this case, it possible to use the audio mute signal of the CPE. Since the CPE must mute the audio once detecting the CAS tone, this signal can also be fed back to the TSPC. The mute signal will have a longer pulse duration than an actual CAS detect pulse. As such the Data Logger must be setup for the longer pulse.

Without any speech signals present, for either test setup A or B, generate 10 or so CAS tone bursts, and record the results with the Data Logger. By viewing the recorded data with the CAS Pulse

Waveform Viewer on the CAS2200 program, determine the average delay of the CAS pulse and its nominal duration. These values should then be entered into the Data Logger such that it can properly classify these pulses as talk-downs. Be sure to add a reasonable tolerance to the start and duration times. Section 3-6 in the CAS2200 User Guide and Reference Manual describes in much more detail how to setup the data logger for receiving and classifying the CAS pulses. Once this is setup, no further changes will be required for doing the talk-down and signal recognition tests.

Signal Recognition Tests

Description

The signal recognition tests determine the ability of the CAS detector to recognize the CAS tone under different signal characteristics. The tests consist of repeatedly sending CAS tones to the CPE with varying frequency, amplitude, and duration. The CPE should be able to receive every CAS tone that was sent. It is recommended that the signal recognition tests be done before the talk-off and talk-down tests, since if problems are detected with signal recognition there is little point in performing the longer and more extensive talk-off and talk-down tests. The following table lists the extreme limits for the CAS tone characteristics along with what is considered the nominal condition.

Parameter	***Nominal***	***Minimum***	***Maximum***
Lower Tone Frequency	*2130 +/- 2 Hz*	*2119 Hz*	*2141 Hz*
Upper Tone Frequency	*2750 +/- 2 Hz*	*2736 Hz*	*2764 Hz*
Power Level per Tone	*-22 +/- 1 dBm*	*-32 dBm*	*-14 dBm*
Power Differential between Tones	*0 to 2 dB*	*0 dB*	*6 dB*
Signal Duration	*80 +/- 1 msec*	*75 msec*	*85 msec*

Table 2: CAS Tone Nominal and Extreme Limits

Various combinations of the above parameter values will be tested by sending 1000 CAS tones to the CPE at a rate not exceeding 2 per second. The CPE should be capable of receiving all of the CAS tones correctly. The various parameter combinations are broken down into three groups described as follows.

- Group 1 consists of all of the parameters at their nominal value.
- Group 2 sets each parameter (one at a time) to its extreme value, while the remaining parameters remain at their nominal value.
- Group 3 sets all parameters to 90% of its extreme value. All of the possible parameter combinations are tested.

There is only one test combination for group 1. Group 2 has 12 combination, and group 3 consists of 48 combinations. In total there are 61 test combinations, with each test requiring 1000 CAS bursts sent. The CPE should receive every CAS burst for every combination. Each test combination requires 34 minutes to complete with 1000 bursts at a 2 second interval.

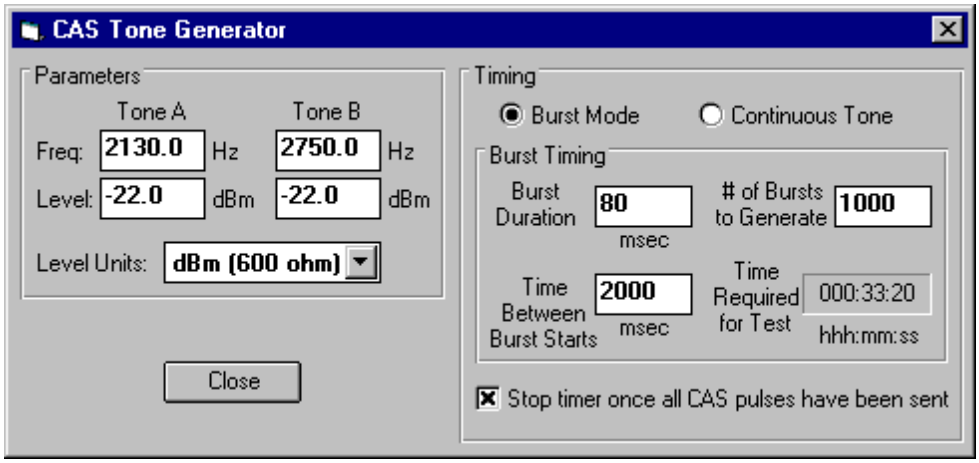
Lastly, a final test is performed to verify that the CAS detector will reject CAS tones that have a signal level lower than - 45 dBm (per tone). At this signal level, the CAS detector should reject all of the CAS

tones. The purpose of this recommendation is to prevent the CAS detector triggering due to signal cross-talk.

CAS2200 Program Setup

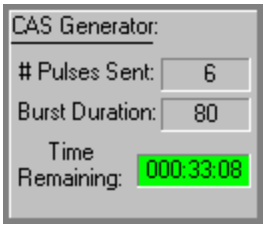
The setup of the CAS2200 program is very straight forward. As previously mentioned, test setup A should be used for the signal recognition tests. The CPE should be off-hook for all tests and the telephone interface impedance set to 900 ohms. The telephone interface panel on the CAS2200 program should look as follows.

All of the CAS tone parameters are set in the following window. This is displayed by either selecting the [Settings] [CAS Tone Generator] menu command, or double-clicking the mouse on the tone generator panel. From the following window, all of the CAS parameters can be adjusted. The frequency and level values are set to the nominal condition, which will be the first test run. Under the timing section of the window, the burst duration is set to 80 msec with 2000 msec between bursts. The number of bursts to send has been set at 1000.



Pressing the “Close” button will remove the setup window. The data logger should be already setup to receive the CAS detect signals from the CPE as described in the above section “Setting up the CAS2200 Data Logger”. If properly setup, the data logger will classify every CAS detect pulse received as a “talk-down/signal recognition” pulse. These can then be viewed graphically in the CAS Pulse Waveform window, or numerically tabulated in the CAS Pules Analysis window. As previously mentioned, all of the 1000 pulses sent should result in 1000 CAS detect pulses received by the data logger.

Starting the test is done by simply pressing the Timer’s Start button, or selecting the [Timer] [Start Timer] menu command. The CAS tone generator panel will show the number of CAS bursts sent along with the time remaining until the test is finished. An example of this is shown below.



The number of pulses received by the data logger should match the number of CAS bursts sent. The test can be halted by pressing the Stop button on the timer, or the test reset by pressing the Reset button. The timer will normally stop once all of the CAS bursts have been sent. Then the "CAS Pulse Analysis" window can be displayed, showing all of the results of the test.

Test Procedure

Group 1 Tests (Nominal Conditions)

The following table shows the parameter settings for the group 1 test. Send 1000 CAS bursts using these values and verify that the CPE responds with 1000 CAS detect pulses.

Test	*Frequency (Hz)*		*Signal Level (dBm)*		*Duration*
Number	*Tone A*	*Tone B*	*Tone A*	*Tone B*	*(msec)*
1	*2130*	*2750*	*-22*	*-22*	*80*

Table 3: Group 1 Test Combinations

Group 2 Tests (Single Extreme Parameter)

For the group 2 tests, use the following table of parameters. There are 12 different combinations of parameter values. For each combination, send 1000 CAS bursts using these values and verify that the CPE responds with 1000 CAS detect pulses

Test	*Frequency (Hz)*		*Signal Level (dBm)*		*Duration*
Number	*Tone A*	*Tone B*	*Tone A*	*Tone B*	*(msec)*
1	***2119***	*2750*	*-22*	*-22*	*80*
2	***2141***	*2750*	*-22*	*-22*	*80*
3	***2130***	***2736***	*-22*	*-22*	*80*
4	*2130*	***2764***	*-22*	*-22*	*80*
5	*2130*	***2750***	***-14***	***-14***	*80*
6	*2130*	*2750*	***-32***	***-32***	*80*
7	*2130*	*2750*	***-14***	***-20***	*80*
8	*2130*	*2750*	***-32***	***-26***	*80*
9	*2130*	*2750*	***-20***	***-14***	*80*
10	*2130*	*2750*	***-26***	***-32***	*80*
11	*2130*	*2750*	***-22***	***-22***	***75***
12	*2130*	*2750*	*-22*	*-22*	***85***

Table 4: Group 2 Test Combinations

Note: The bold face values indicate that they have changed from the previous combination.

Group 3 Tests (Multiple Extreme Parameters)

For the group 3 tests, use the following table of parameters. There are 48 different combinations of parameter values. For each combination, send 1000 CAS bursts using these values and verify that the CPE responds with 1000 CAS detect pulses

Test Number	Frequency (Hz)		Signal Level (dBm)		Duration (msec)
	Tone A	Tone B	Tone A	Tone B	
1	**2120**	**2737**	**-31**	**-31**	**76**
2	2120	2737	-31	**-26**	76
3	2120	2737	**-26**	**-31**	76
4	2120	2737	**-15**	**-15**	76
5	2120	2737	-15	**-20**	76
6	2120	2737	**-20**	**-15**	76
7	2120	2737	**-31**	**-31**	**84**
8	2120	2737	-31	**-26**	84
9	2120	2737	**-26**	**-31**	84
10	2120	2737	**-15**	**-15**	84
11	2120	2737	-15	**-20**	84
12	2120	2737	**-20**	**-15**	84
13	**2140**	2737	**-31**	**-31**	**76**
14	2140	2737	-31	**-26**	76
15	2140	2737	**-26**	**-31**	76
16	2140	2737	**-15**	**-15**	76
17	2140	2737	-15	**-20**	76
18	2140	2737	**-20**	**-15**	76
19	2140	2737	**-31**	**-31**	**84**
20	2140	2737	-31	**-26**	84
21	2140	2737	**-26**	**-31**	84
22	2140	2737	**-15**	**-15**	84
23	2140	2737	-15	**-20**	84
24	2140	2737	**-20**	**-15**	84
25	**2120**	**2763**	**-31**	**-31**	**76**
26	2120	2763	-31	**-26**	76
27	2120	2763	**-26**	**-31**	76
28	2120	2763	**-15**	**-15**	76
29	2120	2763	-15	**-20**	76
30	2120	2763	**-20**	**-15**	76
31	2120	2763	**-31**	**-31**	**84**
32	2120	2763	-31	**-26**	84
33	2120	2763	**-26**	**-31**	84
34	2120	2763	**-15**	**-15**	84
35	2120	2763	-15	**-20**	84
36	2120	2763	**-20**	**-15**	84
37	**2140**	2763	**-31**	**-31**	**76**
38	2140	2763	-31	**-26**	76
39	2140	2763	**-26**	**-31**	76
40	2140	2763	**-15**	**-15**	76
41	2140	2763	-15	**-20**	76
42	2140	2763	**-20**	**-15**	76
43	2140	2763	**-31**	**-31**	**84**
44	2140	2763	-31	**-26**	84
45	2140	2763	**-26**	**-31**	84

46	*2140*	*2763*	***-15***	***-15***	*84*
47	*2140*	*2763*	*-15*	***-20***	*84*
48	*2140*	*2763*	***-20***	***-15***	*84*

Table 5: Group 3 Test Combinations

Note: The bold face values indicate that they have changed from the previous combination.

CAS Level Reject Limit

The last test is performed at the nominal parameter values, except for the signal levels. The signal levels are set to -46 dBm, which should not cause the CAS detector to respond to the CAS bursts.

Test	***Frequency (Hz)***		***Signal Level (dBm)***		***Duration***
Number	***Tone A***	***Tone B***	***Tone A***	***Tone B***	***(msec)***
1	*2130*	*2750*	*-46*	*-46*	*80*

Table 6: CAS Level Reject Combination

Talk-Down Tests

Description

The talk-down test determines the CAS detectors ability to recognize CAS tones in the presence of speech signals. The test is conducted by combining CAS tone bursts and speech signals to the CPE under test and recording how many of the CAS tone bursts were missed by the CPE. This procedure is repeated at various CAS tone levels and speech levels in order to obtain an accurate representation of the detector's performance. Talk-done testing only applies for near-end speech signals, as the CO will normally mute the far-end voice before generating the CAS tone. Depending on the CPE design, test setup A or B will be used for the talk-down testing. If the CAS detector senses the CAS signals from the receive port of the hybrid, then test setup B should be used. Otherwise use the simpler test setup A.

The signal levels used for the talk-down test are given in the following table. Each or the seven combinations of CAS signal level and speech level should be tested.

CAS Signal Level (dBm per tone)	***Active Speech Level (dBm)***	***Signal-to-Speech Ratio (dB)***
-26	*-7*	*-19*
-28	*-13*	*-15*
-22	*-10*	*-12*
-26	*-16*	*-10*
-28	*-22*	*-6*
-22	*-19*	*-3*
-28	*-28*	*0*

Table 7: Talk-down Test Levels

It is assumed that the active speech level (ASL) of the speech source has been measured previously as described in the above section "Measuring the Active Speech Level". If not, that should be done before preceding with the talk-down test, as it can not be measured as the test is running.

Also, if test setup B is used, the worst case telephone test loop should be known using the procedure described in SR-3004.

CAS2200 Program Setup

Depending on which test setup is used, the CAS2200 program configuration will be different. The two following sections indicate the proper configuration for each of the possible test setups.

Test Setup A

For test setup A, the key area's to note are the signal routing and the equalizer settings. The source audio is injected into the BNC input which then passes through the equalizer. In order to simulate the near-end voice, the equalizer is programmed for a pre-emphasis response. The gain setting of the equalizer is adjusted such that the ASL level present at the tip and ring leads matches the desired value stated in table 7. The CAS tone generator should be programmed with the nominal parameter values as given in table 2, except for the signal levels which are defined in table 7. The number of bursts to generate and the interval between the CAS bursts depends on the length of the audio source and the specific timing of the detected CAS pulses. However, the interval should not be less than once every 4 seconds.

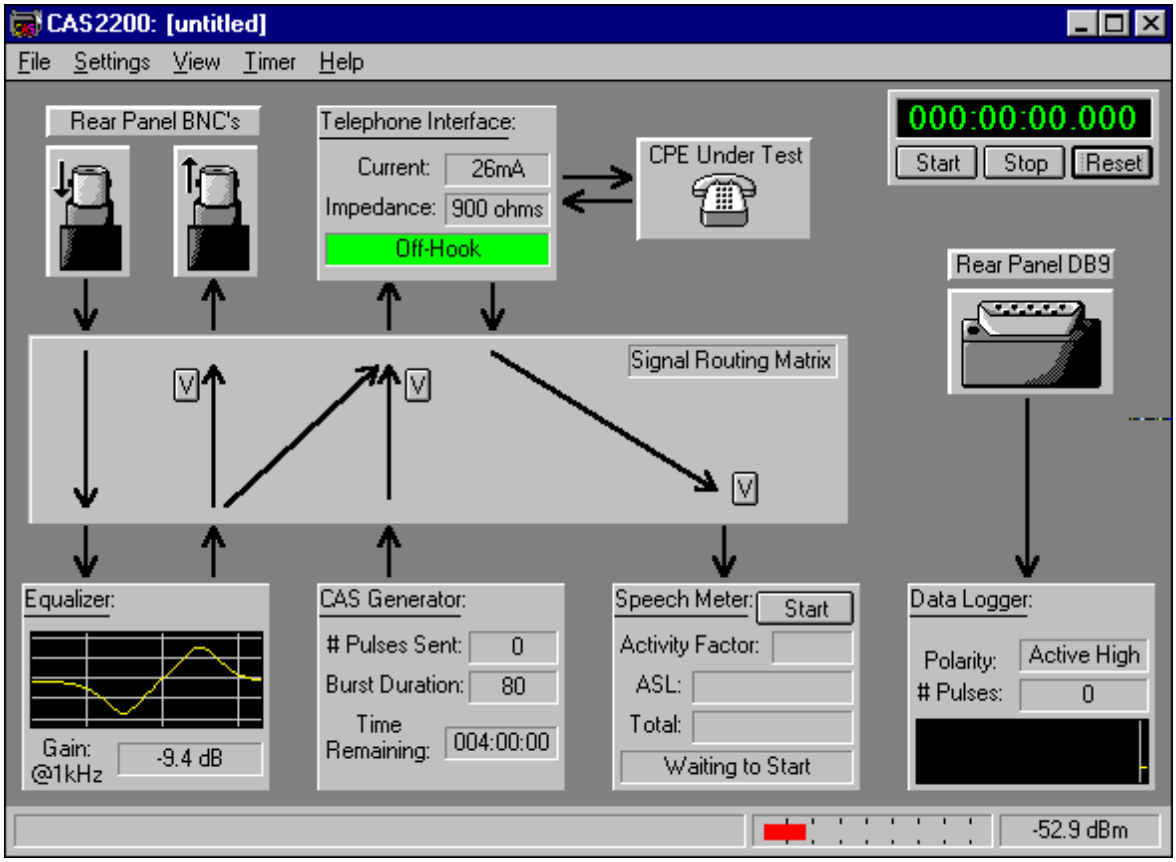


Figure 5: Talk-down Test Setup A

Additionally, the CPE should be off-hook for all tests and the telephone interface impedance set to 900 ohms.

The BNC output connector is not used in this test setup. In Figure 5 it is configured to output the speech signal. However, this can be changed to output the CAS burst or both the voice signal and CAS burst.

The data logger should be already setup to receive the CAS detect signals from the CPE as described in the above section “Setting up the CAS2200 Data Logger”. If properly setup, the data logger will classify every CAS detect pulse received as a “talk-down/signal recognition” pulse. These can then be viewed graphically in the CAS Pulse Waveform window, or numerically tabulated in the CAS Pules Analysis window.

Test Setup B

The configuration for test setup B is significantly different in the area of the signal flow. This is because the level measured at the tip and ring interface of the CPE is sensed by the differential amplifier and then routed to the BNC input of the TSPC. It is important that any gain or loss of the differential amplifier is either offset by loss or gain in the equalizer, or manually taken into account when performing the tests. Also, the equalizer should be set to have a flat frequency response, otherwise the level readings will be affected. Like for test setup A, the CAS tone generator should be programmed with the nominal parameter values as shown in table 2, except for the signal levels which are defined in table 7. The number of bursts to generate and the interval between the CAS bursts depends on the length of the audio source and the specific timing of the detected CAS pulses. However, the interval should not be less than once every 4 seconds.

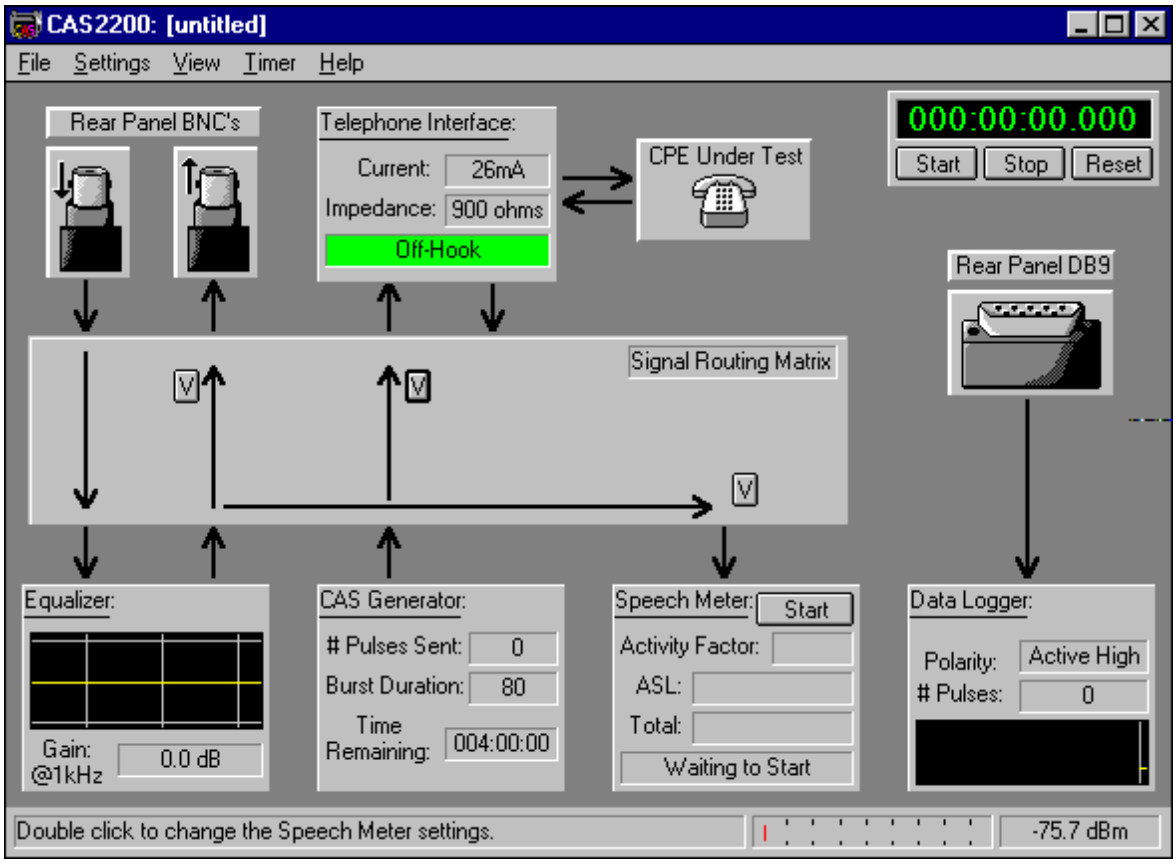


Figure 6: Talk-down Test Setup B

Additionally, the CPE should be off-hook for all tests and the telephone interface impedance set to 900 ohms.

The BNC output connector is not used in this test setup. In Figure 6 it is configured to output the signal from the differential amplifier. However, this can be changed to output the CAS burst or both the voice signal and CAS burst.

The data logger should be already setup to receive the CAS detect signals from the CPE as described in the above section “Setting up the CAS2200 Data Logger”. If properly setup, the data logger will classify every CAS detect pulse received as a “talk-down/signal recognition” pulse. These can then be viewed graphically in the CAS Pulse Waveform window, or numerically tabulated in the CAS Pules Analysis window.

CAS Tone Levels

Part of the talk-down test involves generating the CAS tone bursts at periodic intervals. The proper setup of the CAS tone levels is important in obtaining accurate results. The tone levels can be specified in either units of dBm or dBV. When specified in units of dBm, the signal level will match the entered value when the telephone line is terminated into 600 ohms. This is exactly the situation required for test setup A. So, if test setup A is required, set the CAS tone levels to the values specified in table 7. However, for test setup B, the addition of the test loops will introduce signal loss to the CAS tones. In this case, the loss of the CAS tone must be measured and compensated for. For example, if a per tone level of -22 dBm is required, enable only the low frequency CAS tone at a level of -22 dBm. Measure the level at the CPE by using the RMS signal level meter present on the status bar. Most likely, the reading will be less than -22 dBm. Calculate the difference, and adjust the generator’s output level. Now, repeat with only the high frequency CAS tone enabled. Record the signal loss, and adjust the generator level to compensate. Once the signal loss is known at both the CAS tone frequencies, the correct level at the CPE can be set by compensating for the signal loss through the test loops.

Test Procedure

Starting the test is done by simply pressing the timer’s Start button, or selecting the [Timer] [Start Timer] menu command and simultaneously starting the playback of the speech material. The CAS tone generator panel will show the number of CAS bursts sent along with the time remaining until the test is finished. It is possible to stop the test in progress by pressing the timer Stop button, or selecting the [Timer] [Stop Timer] menu command. The current test can then be re-started by pressing the Start button. This method of temporarily pausing the test can be used to change the audio source tape. Pressing the Reset button will stop and reset the test back to the beginning. All the data collected will be lost when Reset is pressed.

Once the test has been completed by sending all of the CAS bursts, or pressing the Stop button, the data collected can be viewed in the “CAS Pulse Analysis” window. Even as the test is running, it is possible to view the current test results by pressing the Update button in the “CAS Pulse Analysis” window. The number of CAS pulses received and the number of CAS pulses sent should be recorded for further analysis. Note that the data logger can only store data for 32,000 signal transitions. This normally represents 16,000 CAS detect pulses, provided the signal source is glitch free. As such, the test lengths should be less than 16,000 CAS tone bursts.

The entire test cycle is repeated for each of the CAS signal and speech level combinations shown in Table 7. Once all the tests are complete, it should be possible to complete the table below.

CAS Level (dBm / tone)	Speech Level (dBm)	Signal-to-Speech Ratio (dB)	Number of CAS Pulses Received	Number of CAS Bursts Sent	De-rated Miss Rate (%)
-26	-7	-19			
-28	-13	-15			
-22	-10	-12			
-26	-16	-10			
-28	-22	-6			
-22	-19	-3			
-28	-28	0			

Table 8: Talk-down Results

Determining the Results

The data collected can be entered into the CAS Performance Calculator, which will compute the final results of the talk-down test. Figure 7 shows a sample entry of the talk-down results in the CAS Performance Calculator. A minimum of two data points are required for the performance calculator to compute the results. However, the use of only two data points will not yield overly accurate results. It is possible to enter the data points as the talk-down test is running. This way an approximation of the talk-down performance can be determined before all that data has been collected. In this approach, it makes the most sense to perform the talk-down testing at the extremes of the "Signal-to-Speech" ratio first. These two data points can be entered to give an approximation of the performance, which will most likely be overly conservative. As more tests are run, those data points can be entered. As the process continues a more accurate result will be generated.

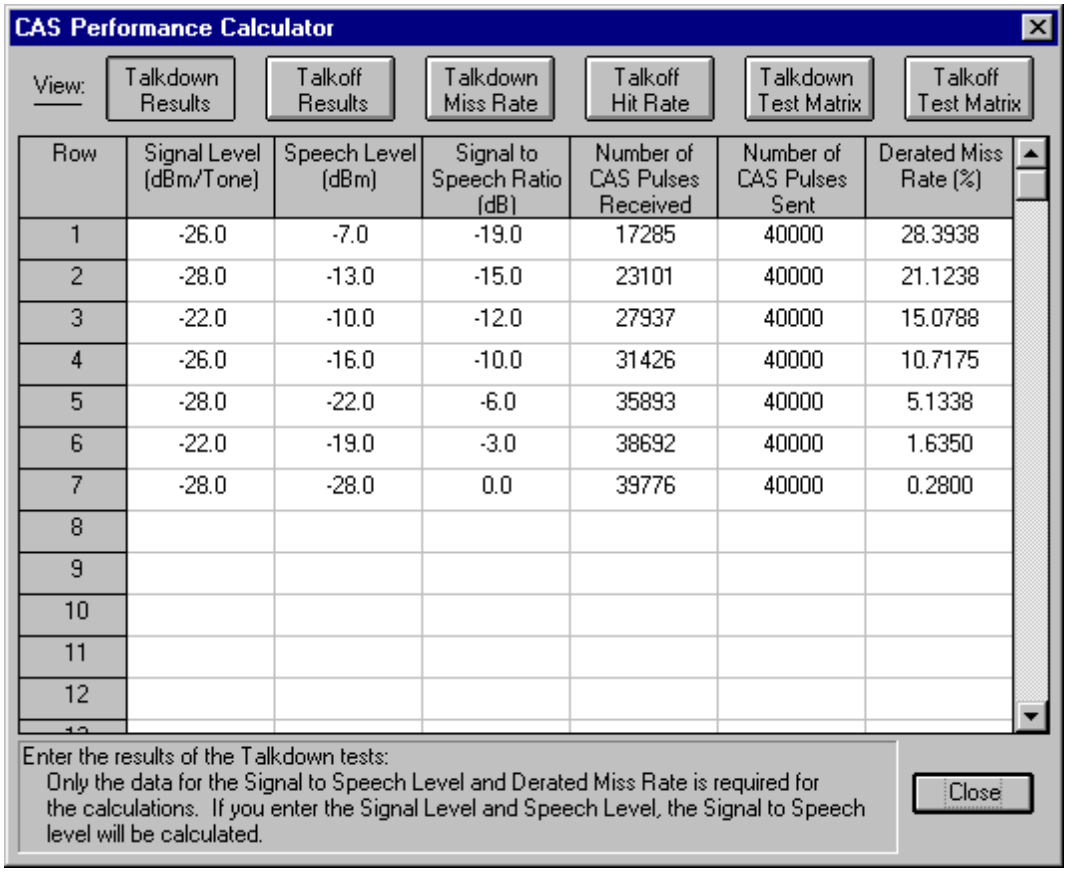
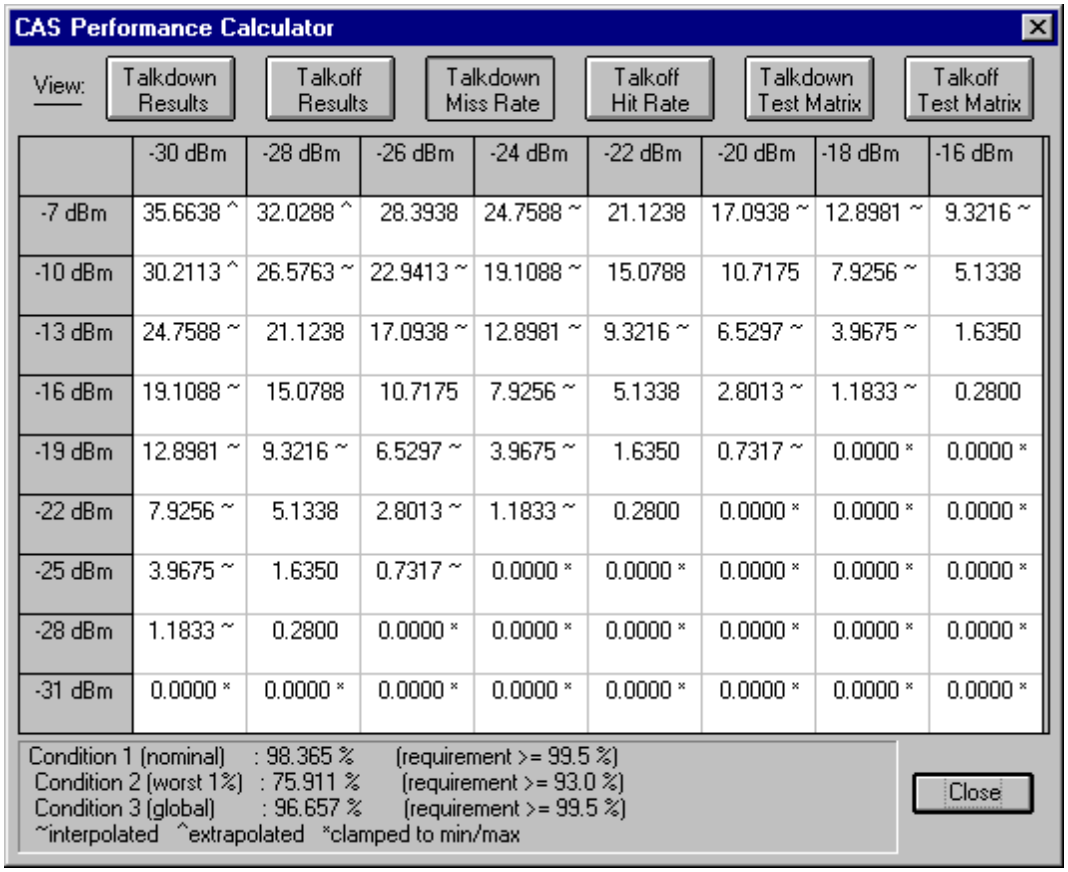


Figure 7: Entering the Raw Talk-down Performance Data

Once at least two data points have been entered, pressing the Talkdown Miss Rate button will display the miss rate matrix as shown in figure 8. If any data entry error was detected in the results table, an error will be generated and the Talkdown Miss Rate table will not be displayed.



	-30 dBm	-28 dBm	-26 dBm	-24 dBm	-22 dBm	-20 dBm	-18 dBm	-16 dBm
-7 dBm	35.6638 ^	32.0288 ^	28.3938	24.7588 ~	21.1238	17.0938 ~	12.8981 ~	9.3216 ~
-10 dBm	30.2113 ^	26.5763 ~	22.9413 ~	19.1088 ~	15.0788	10.7175	7.9256 ~	5.1338
-13 dBm	24.7588 ~	21.1238	17.0938 ~	12.8981 ~	9.3216 ~	6.5297 ~	3.9675 ~	1.6350
-16 dBm	19.1088 ~	15.0788	10.7175	7.9256 ~	5.1338	2.8013 ~	1.1833 ~	0.2800
-19 dBm	12.8981 ~	9.3216 ~	6.5297 ~	3.9675 ~	1.6350	0.7317 ~	0.0000 *	0.0000 *
-22 dBm	7.9256 ~	5.1338	2.8013 ~	1.1833 ~	0.2800	0.0000 *	0.0000 *	0.0000 *
-25 dBm	3.9675 ~	1.6350	0.7317 ~	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *
-28 dBm	1.1833 ~	0.2800	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *
-31 dBm	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *	0.0000 *

Figure 8: Talk-down Miss Rate Matrix and Final Results

The end result of the talk-down testing generates the success rate for three different conditions. These conditions are:

- Talk-down condition 1: The success rate of detecting the CAS bursts at an average signal level of -22 dBm and average speech level of -19 dBm. The result should be greater than 99.5%.

- Talk-down condition 2: The success rate of detecting the CAS bursts at a weighted average of the worst 1.22% of the signal-to-speech ratios. This average is weighted based on the joint probability of the signal and speech levels. The result should be greater than 93%.

- Talk-down condition 3: The success rate of detecting the CAS bursts over a weighted average of all signal and speech levels. This average is weighted based on the joint probability of the signal and speech levels. The result should be greater than 99.5%.

The results of the above three conditions are shown on the bottom of figure 8. A hardcopy report can be generated by the CAS2200 program by selecting the appropriate printing option from the File menu.

Talk-Off Tests

Description

The talk-off test can be basically thought of the complement of the talk-down test. Where as the talk-down test determines the CAS detectors ability to recognize CAS tones in the presence of speech and noise, the talk-off test measures the CAS detectors ability not to falsely interpret speech and noise as CAS tones. The two goals of having acceptable talk-off and talk-down performance generally oppose each other and thus it can become difficult to locate an acceptable compromise. The test for talk-off is very similar to that of talk-down, except that no CAS bursts are generated. Any false detects by the CAS detector are termed 'hits', with the detector's performance measured in hits per hour.

However, unlike the talk-down test, the talk-off test must be performed for both near-end and far-end voice. The general procedure is to expose the CAS detector to a speech source and observe the number of hits per hour. The level of the speech source is varied over a prescribed range, and then repeated for both near-end and far-end voice. Depending on the CPE design, test setup A or B will be used for the talk-down testing. If the CAS detector senses the CAS signals from the receive port of the hybrid, then test setup B should be used for near-end voice. Otherwise use the simpler test setup A for near-end voice. In either case, test setup A will be used for the far-end voice.

The Bellcore SR-TSV-002476 document recommends performing the talk-off test at the following speech levels.

Near-End Speech Level (dBm)	***Far End Speech Level (dBm)***
-7	*-7*
-10	*-10*
-13	*-13*
-16	*-16*
-19	*-19*
-22	*-22*
-25	*-25*
-28	*-28*
-31	*-31*

Table 9: Talk-off Test Levels

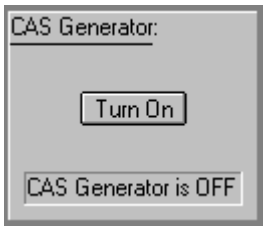
It is assumed that the active speech level (ASL) of the speech source has been measured previously as described in the above section "Measuring the Active Speech Level". If not, that should be done before preceding with the talk-down test, as it can not be measured as the test is running.

Also, if test setup B is used for the near-end voice, the worst case telephone test loop should be known using the procedure described in SR-3004.

CAS2200 Program Setup

The program configuration is very similar to that of the talk-down test. The main difference is that the CAS generator should be disabled, since no CAS pulses are generated for the talk-off test. Disabling the CAS generator can be accomplished by changing the CAS generator mode to "Continuous Tone"

from “Burst Mode” in the CAS Generator Settings window. This will alter the display of the CAS generator panel to the following:



In this mode, the CAS generator can be turned on or off by clicking the center button. However, for the talk-off testing, the generator must be left off.

Depending on which test setup is used, the CAS2200 program configuration will be different for the near-end voice. For far-end voice, only test setup A will be used. The two following sections indicate the proper configuration for each of the possible test setups.

Test Setup A

For test setup A, the key area’s of note are the signal routing and the equalizer settings. The source audio is injected into the BNC input which then passes through the equalizer.
If this setup is used for near-end voice, then the equalizer is programmed for a pre-emphasis. Otherwise, for far-end voice, the equalizer should have a flat response.
The gain setting of the equalizer is adjusted such that the ASL level present at the tip and ring leads matches the desired value stated in table 9. As shown in figure 9, the CAS generator has been disabled for the talk-off tests.

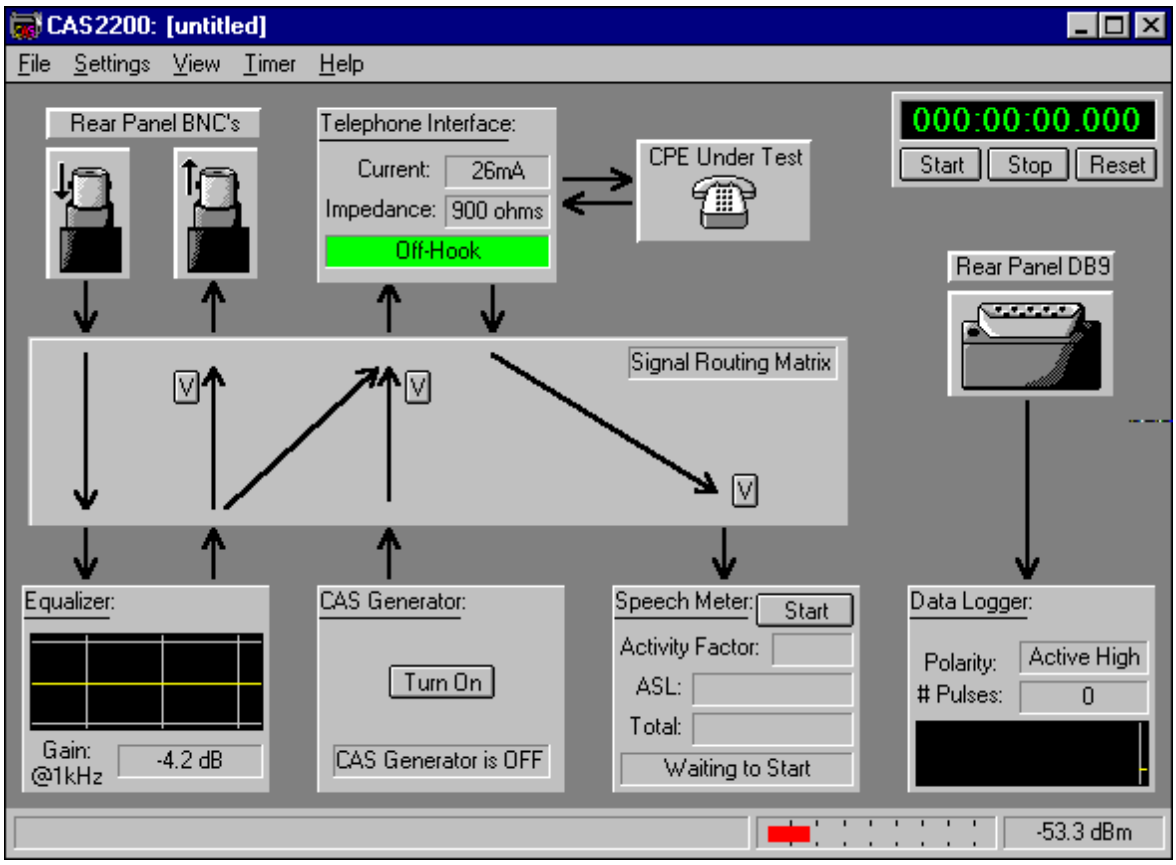


Figure 9: Talk-off Test Setup A (far end voice)

Additionally, the CPE should be off-hook for all tests and the telephone interface impedance set to 900 ohms.

The data logger should be already setup to receive the CAS detect signals from the CPE as described in the above section “Setting up the CAS2200 Data Logger”. If properly setup, the data logger will classify every falsely CAS detect pulse received as a “talk-off” pulse. These can then be viewed graphically in the CAS Pulse Waveform window, or numerically tabulated in the CAS Pules Analysis window.

Test Setup B

Test setup B will only be used for the near-end talk-off tests if the CPE’s CAS detector takes its input from the receive port of the CPE’s hybrid. The program configuration is identical to that of the talk-down test for setup B, except that the CAS generator has been disabled by setting to the continuous mode of operation. In this setup the level measured at the tip and ring interface of the CPE is sensed by the differential amplifier and then routed to the BNC input of the TSPC. It is important that any gain or loss of the differential amplifier is either offset by loss or gain in the equalizer, or manually taken into account when performing the tests. Also, the equalizer should be set to have a flat frequency response, otherwise the level readings will be affected.

Additionally, the CPE should be off-hook for all tests and the telephone interface impedance set to 900 ohms.

Like setup A, the data logger should be already setup to receive the CAS detect signals from the CPE as described in the above section “Setting up the CAS2200 Data Logger”. If properly setup, the data logger will classify every falsely CAS detect pulse received as a “talk-off” pulse. These can then be viewed graphically in the CAS Pulse Waveform window, or numerically tabulated in the CAS Pules Analysis window.

Test Procedure

Starting the test is done by simply pressing the timer’s Start button, or selecting the [Timer] [Start Timer] menu command and simultaneously starting the playback of the speech material. The Timer will start to increment and any signals detected by the data logger will be recorded. It is possible to stop the test in progress by pressing the timer Stop button, or selecting the [Timer] [Stop Timer] menu command. The current test can then be re-started by pressing the Start button. This method of temporarily pausing the test can be used to change the audio source tape. Pressing the Reset button will stop and reset the test back to the beginning. All the data collected will be lost when Reset is pressed.

When all the audio tapes have been played, pressing the Stop button will suspend the data collection and any CAS pulses detected can be viewed in the “CAS Pulse Analysis” window. Even as the test is running, it is possible to view the current test results by pressing the Update button in the “CAS Pulse Analysis” window. For talk-off tests, the total test time will be displayed along with the number of talk-off pulses detected, and the de-rated hit rate per hour.

The entire test cycle is repeated for each of the speech levels shown in Table 9 for both near-end and far-end voice. Once all the tests are complete, it should be possible to complete the table below.

Near-End Speech Level (dBm)	*Number of Near-End Hits*	*Near-End Test Time (hours)*	*Far-End Speech Level (dBm)*	*Number of Far-End Hits*	*Far-End Test Time (hours)*
-7			*-7*		
-10			*-10*		
-13			*-13*		

-16			*-16*		
-19			*-19*		
-22			*-22*		
-25			*-25*		
-28			*-28*		
-31			*-31*		

Table 10: Talk-off Results

Determining the Results

The data collected can be entered into the CAS Performance Calculator, which will computer the final results of the talk-off test. Figure 10 shows a sample entry of the talk-off results in the CAS Performance Calculator. A minimum of two data points are required for the performance calculator to compute the results. However, the use of only two data points will not yield overly accurate results. It is possible to enter the data points as the talk-off test is running. This way an approximation of the talk-off performance can be determined before all that data has been collected. In this approach, it makes the most sense to perform the talk-off testing at the extremes of the speech levels first. These two data points can be entered to give an approximation of the performance, which will most likely be overly conservative. As more tests are run, those data points can be entered. As the process continues a more accurate result will be generated.

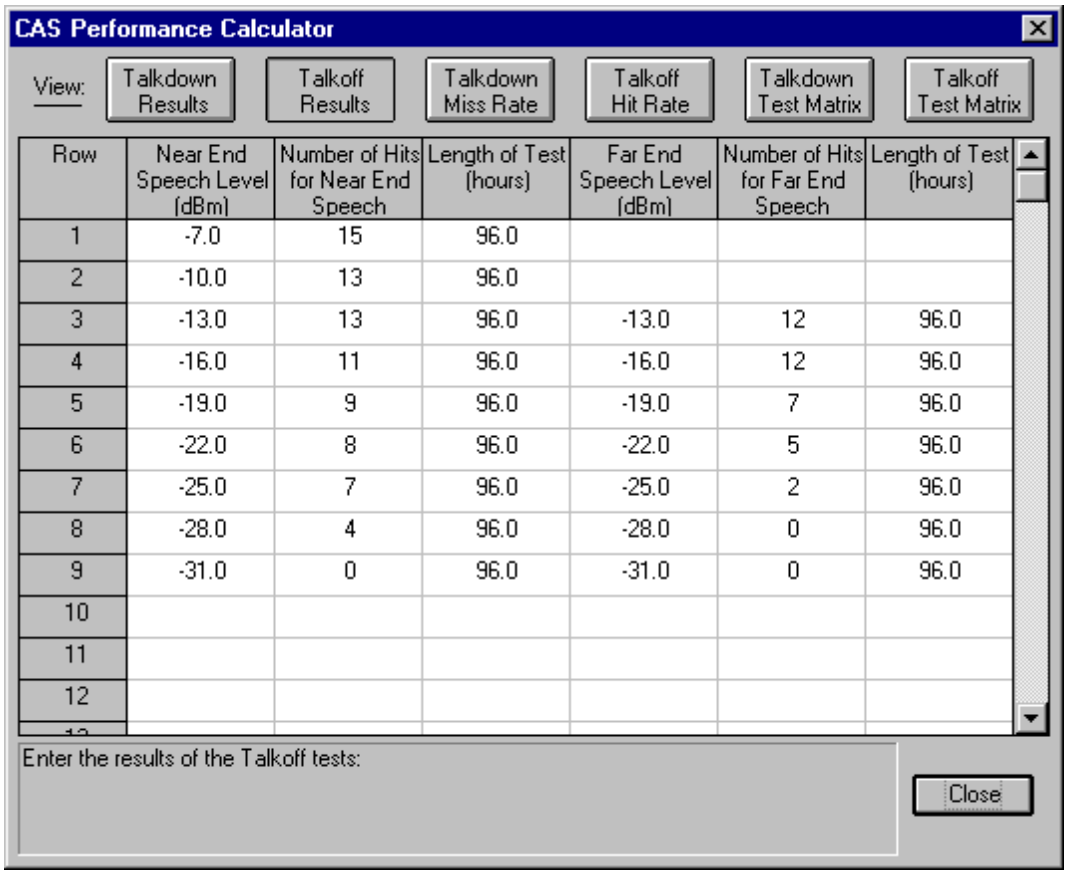
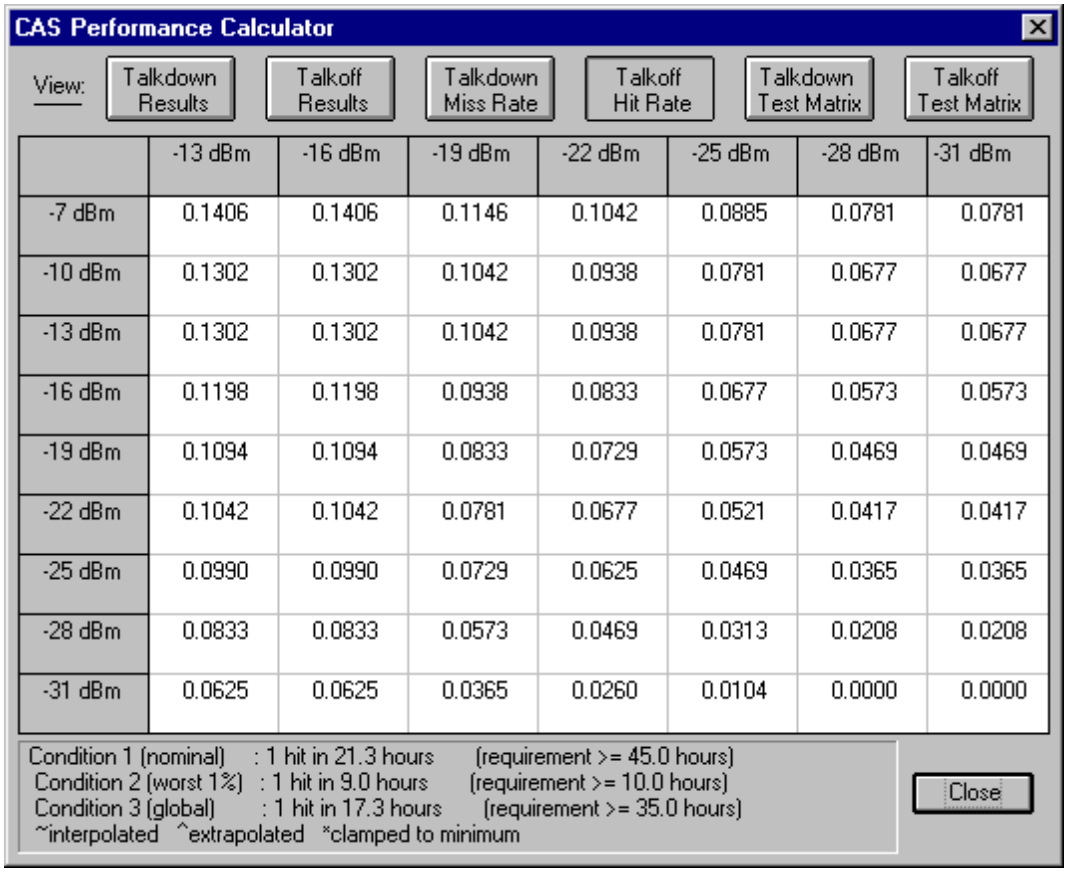


Figure 10: Entering the Raw Talk-off Performance Data

Once at least two data points have been entered, pressing the Talkoff Hit Rate button will display the hit rate matrix as shown in figure 11. If any data entry error was detected in the results table, an error will be generated and the Talkoff Hit Rate table will not be displayed.



	-13 dBm	-16 dBm	-19 dBm	-22 dBm	-25 dBm	-28 dBm	-31 dBm
-7 dBm	0.1406	0.1406	0.1146	0.1042	0.0885	0.0781	0.0781
-10 dBm	0.1302	0.1302	0.1042	0.0938	0.0781	0.0677	0.0677
-13 dBm	0.1302	0.1302	0.1042	0.0938	0.0781	0.0677	0.0677
-16 dBm	0.1198	0.1198	0.0938	0.0833	0.0677	0.0573	0.0573
-19 dBm	0.1094	0.1094	0.0833	0.0729	0.0573	0.0469	0.0469
-22 dBm	0.1042	0.1042	0.0781	0.0677	0.0521	0.0417	0.0417
-25 dBm	0.0990	0.0990	0.0729	0.0625	0.0469	0.0365	0.0365
-28 dBm	0.0833	0.0833	0.0573	0.0469	0.0313	0.0208	0.0208
-31 dBm	0.0625	0.0625	0.0365	0.0260	0.0104	0.0000	0.0000

Figure 11: Talk-down Miss Rate Matrix and Final Results

The end result of the talk-off testing generates the hit rate for three different conditions. These conditions are:

- Talk-off condition 1: The time between false CAS detection events at an average near-end level of -22 dBm and average far-end level of -28 dBm. The result should be less than 1 occurrence in 45 hours.

- Talk-off condition 2: The time between false CAS detection events at a weighted average of the highest 1.14% of the near and far end speech levels. This average is weighted based on the joint probability of the speech levels. The result should be less than 1 occurrence in 10 hours

- Talk-off condition 3: The time between false CAS detection events over a weighted average of all near and far end speech levels. This average is weighted based on the joint probability of the near and far end speech levels. The result should be less than 1 occurrence in 35 hours

The results of the above three conditions are shown on the bottom of figure 11. A hardcopy report can be generated by the CAS2200 program by selecting the appropriate printing option from the File menu.

Hints and Shortcuts

The complete test procedure as described in SR-TSV-002476 and SR-3004 can require a long time to complete. This depends mostly on the number of hours that is allocated to each of the talk-down and talk-off test runs. The above mentioned Bellcore documents do not explicitly state the number of hours these tests should be run for. This leads to some confusion as to how long is enough. Given the performance recommendations for the talk-off test alone, it would indicate that a least 45 hours of testing is needed to confirm condition 1. Since it is recommended that the Bellcore speech material be used in these test procedures for consistent results, that imposes an upper limit of 96 hours for testing. This is because there is little point in repeating the same speech material for the talk-off test.

In any case a lot of judgment is required in assessing how long to run the tests for. In the CPE development stage it may not be necessary for the full length test runs; where as, for final design verification it would make more sense to perform a very extensive test run. Also in the development stages the testing time could be reduced by not testing at every data point, or by just targeting the data points that prove to be the most troublesome. Finally, as the talk-down or talk-off test is being run, it is reasonable to terminate the test early provided the miss rate or hit rate has stabilized and sufficient events have occurred to insure a reasonable degree of confidence in the result. For example, in performing the talk-down tests at very low signal-to-speech levels, a large number of CAS bursts will be missed by the detector. Because of the large number of misses, the miss rate will normally settle down at a faster rate than at high signal-to-speech levels. By calculating the miss rate periodically during the test and checking if it has in fact stabilized, it would be reasonable to terminate the test early and save some time. These techniques can become useful in the development stages.

Combining the Talk-Off and Talk-Down Tests

The technique of combining the talk-off and talk-down tests can become a very significant method of reducing the test time. This approach is only valid for the near-end talk-off, not the far-end talk-off, which would still have to be tested separately. The basic premise is that when performing a talk-down test, the time interval between CAS bursts can used to sense for talk-off hits. The AI 240 is capable of classifying the detected CAS pulses into talk-down or talk-off pulses depending on the timing of the received pulse in relationship to when the CAS burst was generated. The talk-down event must be specified to occur in a defined region of time surrounding the generated CAS burst. Outside the valid talk-down region a guard time is added, and the remaining time between bursts is considered as the talk-off test time. With this method the talk-down and talk-off tests are interleaved. The actual talk-off test time will be de-rated since only part of the total test time is allocated to the talk-off test. As an example, 100 hours of total test time may yield only 90 hours of talk-off test time. The AI 240 will take this de-rating factor into account when computing the talk-off test time. The most important aspect of combining the two tests is to verify that the time window for the talk-down events and the guard time are sufficient such that a talk-down event will not be mistaken for a talk-off hit.

Combining the Near-End and Far-End Talk-Off Tests

It is possible to combine the near-end and far-end talk-off tests provided the CPE does not sense the CAS signal from the receive port of the CPE's hybrid. Thus if test setup A can be used for both near-end and far-end talk-off testing, it is possible to combine the tests together. For test setup A, the only difference between the two is that for the near end voice, pre-emphasis is applied. However, if pre-emphasis is applied for both the far end and near end, then only one set of data points is required. The effect of adding the pre-emphasis to the far-end voice will usually result in a more conservative result of the CPE's talk-down performance. If no pre-emphasis is used for either the near-end or far-end, then the results will usually be overly optimistic. In either case, the length of time needed to perform the testing will be cut in half, which may be worth the inaccuracies added to the results.

Simplifying the Tests Involving Trans-Hybrid Loss

For CPE's that sense the CAS signal from the hybrid's receive port, the more complex test setup B must be used for the talk-down and near-end talk-off tests. This also prevents the near-end and far-

end talk-off tests from being combined. However it is possible to use test setup A for these types of CPE's under certain conditions. This would greatly simplify testing as the talk-down, near-end talk-off, and far-end talk-off tests can all be combined together. The key to this approach is to factor in the effect of the trans-hybrid loss after the data has been collected. The value of the trans-hybrid loss for the CPE must be measured, and it should be relatively flat over the voice band frequency response (300 Hz to 3 kHz). All of the tests are performed assuming that the CPE senses the CAS signal from the tip and ring leads, and thus test setup A can be used. However, when entering the talk-down data into the CAS performance calculator, the signal-to-speech ratios are reduced by the amount of the trans-hybrid loss. This is because had the near-end speech been applied acoustically to the CPE, the level seen by the CAS detector would of been reduced by the amount of the trans-hybrid loss. For the near-end talk-off data, the near-end signal level should be increased by the amount of the trans-hybrid loss. This is because had the speech been acoustically applied, the effect of the hybrid would reduce the level at the CAS detector by the trans-hybrid loss. Since the signal was rather applied at the tip and ring interface, the effect of the trans-hybrid loss has to be added to what the acoustically coupled signal level would of been.

This procedure, while simplifying the testing greatly, is based on the assumption that the trans-hybrid loss has a reasonably flat response with frequency. If this is not the case or the CAS detector is sensitive to the frequency response variations over the entire voice band, then this simplification may not be valid.

Reducing the Talk-off Test Points

If the far-end talk-off test is performed separately from the near-end talk-off test, there is no need to test at the speech levels of -7 dBm and -10 dBm, since they are outside the Bellcore talk-off test matrix of joint probabilities. Assuming that the level of -13 dBm has been tested to, then the additional data at -7 dBm and -10 dBm will have no effect on the final talk-off results. This saves 2 data points and can reduce the test time accordingly.