Information in Sage's P.561 INMD Test

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1 Introduction

INMD stands for In-service Non-intrusive Measurement Device. It is a passive voice quality monitoring method based on ITU-T P.561 [1]. Two types of measurements are covered by INMD: 1, speech and noise characterization; 2, echo characterization. Sage's current implementation of INMD on the 960 platform focuses only on echo characterization. More specifically, once the presence of echo is detected, Sage's INMD in 960 will report in real time the detected echo level and echo delay. A graphical snapshot of the reference and echo signals is also displayed as further visual confirmation. If the monitored DS1 are PRI-ISDN lines, then the source and destination phone numbers associated with the monitored DS0 channel are also presented.

2 Test Configuration

When using INMD, a user should connect Sage's 960 to the network as shown in Figure 1. Sage's 960
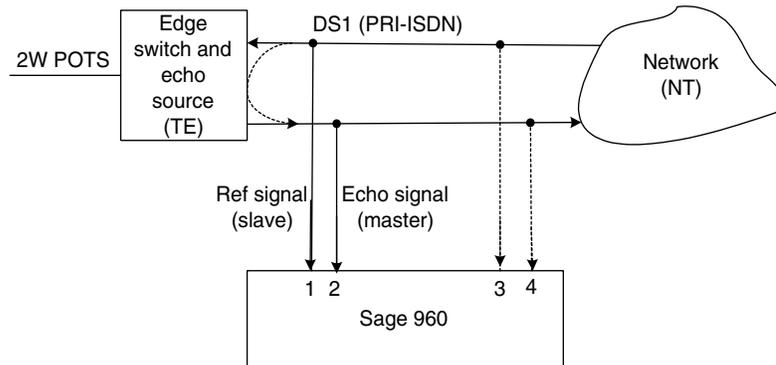
Figure 1: Connection diagram for running INMD on Sage's 960.

has 4 DS1 spans, numbered as PCM1, PCM2, PCM3 and PCM4. Internally, PCM1 and PCM2 are a pair controlled by one embedded processor, whereas PCM3 and PCM4 are another pair controlled by another embedded processor. Since INMD entails precise relative delay measurement between two input signals, Sage's 960 must be configured in the following ways:

1. Two DS1 spans are used for INMD, although only the receiving ports need to be connected. The two DS1 spans must be either the PCM1 and PCM2 pair, or the PCM3 and PCM4 pair. Other combinations such as PCM1 and PCM4 or PCM2 and PCM3 etc are not allowed.

2. The chosen DS1 pair must be configured to "DUAL MONITOR" mode. When performing span configuration through 960's GUI, one only needs to (and must) configure the first span (PCM1 or PCM3) of each DS1 pair. The partner DS1 span (PCM2 or PCM4) will be configured automatically for you. A user configuration on the second DS1 span (PCM2 or PCM4) has no effect. In "DUAL MONITOR" mode, the internal software will always set the DS1 clock source to "EXTERNAL LOOP CLOCK" regardless what the user selects on the GUI.

3. The INMD on 960 includes two seemingly separate tests that in practice must be treated as an atomic pair. The 960 GUI names the tests as "INMD-SLAVE" and "INMD-MASTER". The "INMD-SLAVE" must be run on a DS0 channel of the first DS1 span (PCM1 or PCM3) that is physically connected to the incoming reference signal. The "INMD-MASTER" must be run on the same DS0 channel of the second DS1 span (PCM2 or PCM4) that is physically connected to the incoming echo signal. The measurement results are only available at the "INMD-MASTER" side.

4. If the DS1 lines being monitored are PRI-ISDN lines, then the D-channel must be specified correctly when performing the span configuration in order for INMD to intercept the source and destination phone numbers associated with the DS0 channel(s) being monitored. If one is also interested in decoding all the ISDN call messages, one should also specify the TE and NT modes correctly. As in "TERMINATE" mode, the 960 DS1 span should be set to match the incoming NT or TE mode. For example, as shown in Figure 1, if the signal goes into the receiving port of PCM1 is from the NT equipment, then 960's PCM1 must be set to TE mode. Internally, the PCM2 will automatically be set to NT mode to match the signal from the TE equipment.

3   Operation principles

Simply speaking, INMD detects echo by principle of cross-correlation. More specifically, as implemented in Sage's 960, both "INMD-SLAVE" and "INMD-MASTER" have an internal signal-analyzing window of 256 ms long (2048 samples at 8000Hz sampling rate). The presence of echo is declared when all of the following conditions are met:

1. The echo signal side ("INMD-MASTER" side) analyzing window captured some signal ($e(n)$) whose power level (P_e) is greater than -60 dBm.

2. The reference signal side ("INMD-SLAVE" side) analyzing window also captured some signal ($r(n)$) whose power level (P_r) is greater than P_e.

3. Circular cross-correlation is performed between $r(n)$ and $e(n)$:

$$cor(n) = \sum_{m=0}^{2047} r(m)e((m+n)\%2048), n = 0, 1, 2, \ldots, 2047$$

where % represents modular (remainder) calculation. In actual implementation, the circular correlation is obtained through two forward FFTs and one inverse FFT. The FFT-based approach is far more efficient than the direct brute-force computation. An example of the

signal $r(n)$, $e(n)$ and their circular-cross-correlation is shown in Figure 2. In Figure 2, the correlation trace has been normalized as

$$cor_{normalized}(n) = \frac{cor(n)}{\sqrt{\sum r^2(n) \sum e^2(n)}}$$

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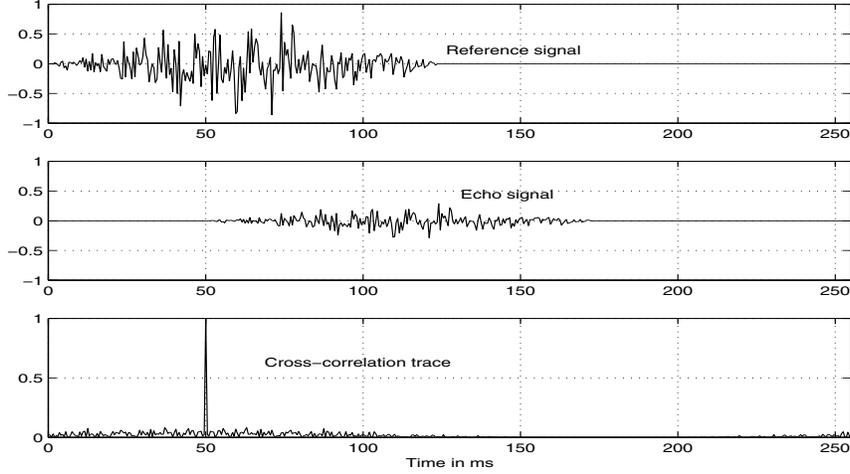
Figure 2: An exemplary reference signal, echo signal and their normalized cross-correlation trace. In this example, the echo path is flat. Echo delay is 50 ms and echo level is -10 dB.

4. Check to see if $r(n)$ and $e(n)$ are narrow-band tone signals. If yes (they are tone signals), then ignore the captured signals, and restart capturing new signals again. Mathematically speaking, the cross-correlation $cor(n)$ will truly resemble the echo impulse response $h(n)$ only if the reference signal $r(n)$ is "white noise" that has flat spectrum in frequency domain. If $r(n)$ is a "highly-colored" narrow-band tone signal, then the obtained $cor(n)$ does not resemble the echo impulse response $h(n)$ because the excitation signal $r(n)$ did not excite all aspects (all spectrum) of the "system" (echo path). More specifically, the echo delay measurement will be affected. This is a classical signal processing problem, not a problem specific to Sage's implementation. If $r(n)$ and $e(n)$ are determined to be valid voice-like complex signals, then the INMD algorithm will proceed to the following steps.

5. Locate the peak on $|cor(n)|$, and record the index ix that corresponds to the peak. Then re-compute the "linear" cross-correlation at the following 8 points (within 1 ms span):

$$R(n) = \sum_{m=0}^{2047-ix-n} r(m)e(ix+m+n), n = 0,1,2,3,4,5,6,7$$

Then calculate the following ratio:

$$ratio = \frac{\sum_{n=0}^{7} R^2(n)}{\sum_{n=0}^{2047-ix} r^2(n) \sum_{n=ix}^{2047} e^2(n)}$$

If this ratio is greater than 0.36, then the presence of an echo is detected, and $ix/8$ is the echo delay in ms. The echo level is computed as:

$$EchoLevel_{dB} = 10 \log 10(\frac{\sum_{n=ix}^{2047} e^2(n)}{\sum_{n=0}^{2047-ix} r^2(n)})$$

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The reasons for performing the linear cross-correlation at 8 points and later summing up their total "contribution" is to account for the dispersion effect that is always present on a real echo path.

6. The delay adjusted signals $r(n)$ and $e(n + ix)$ are sent to the display in linear scale. Since the analyzing window size is set to 256 ms, an echo with delay longer than 256 ms will not be detected. The presence of echo is detected and reported within 256 ms.

References

[1] "In-service non-intrusive measurement device-Voice service measurements," *ITU-T Recommendation P.561*, July, 2002.