Release date	Download more Info	Contact person
May, 2005	http://www.acterna.com	Mike Krasnow Product Marketing Engineer Tel: +1 240 404 2532 E-mail: mike.krasnow@acterna.com

Copper Testing for ADSL/2/2+

Qualification and troubleshooting of the local loop

Summary

Today's widespread growth in deployment of higher speed DSL service, such as ADSL/2/2+, enables telecom service providers to offer voice, video, and data over a single twisted pair of copper wires. This is termed the "triple play" of the telecommunications industry.

For the successful adoption of triple play services, providers must meet or exceed the quality of service offered by traditional cable television and plain old telephone service (POTS). Faults in the copper pair create faults in the ADSL signal, which leads to lost packets and transmission delays. These lost packets and delays create slow data rates and degrade the quality of voice and video services. For triple play services to be profitable, providers must reduce excessive dispatches, customer churn, and repeat service rates. Proper qualification and troubleshooting of the copper pair is critical to achieve customer satisfaction and reduce repair costs.

This Acterna white paper discusses line qualification and troubleshooting for ADSL/2/2+, describing the common problems that affect service and how to identify them.

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ADSL Overview

A single copper pair delivers both POTS service and ADSL service by carrying three channels - a high-speed downstream channel, a medium-speed upstream channel, and a POTS channel.

An ADSL transceiver unit-remote (ATU-R) is located at the customer's premises, and an ADSL transceiver unit-central office (ATU-C) is located at the central office. The ATU-C is a circuit card mounted in a digital subscriber line access multiplexer (DSLAM). The subscriber connects their modem to an RJ-11 outlet in the wall and their PC to the modem, typically with a RJ-45 or USB connector (Figure 1).

The POTS signal is transmitted in the low frequency band below 4 kHz. Upstream ADSL/2/2+ data is carried between 25 kHz and 138 kHz. Downstream data is carried between 139 kHz and 1.1 MHz for ADSL and ADSL2. ADSL2+ uses a downstream bandwidth of 139 kHz to 2.2 MHz (Figure 2). Selection of the copper pair is very important, since line length, bridged taps, and cross-coupled interference all degrade the data rate.

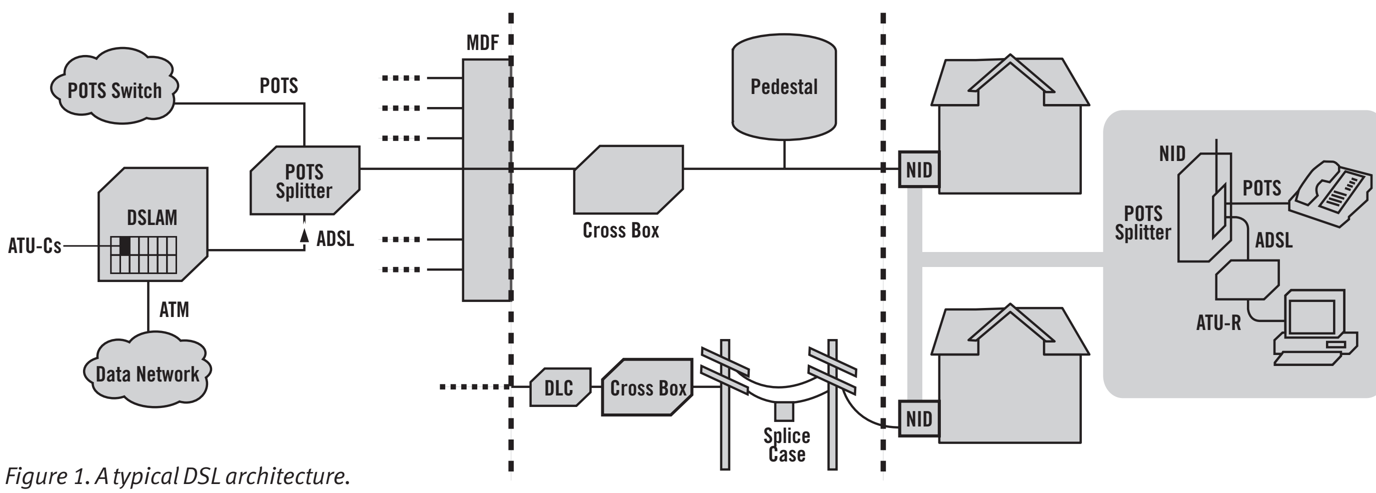

Figure 1. A typical DSL architecture.

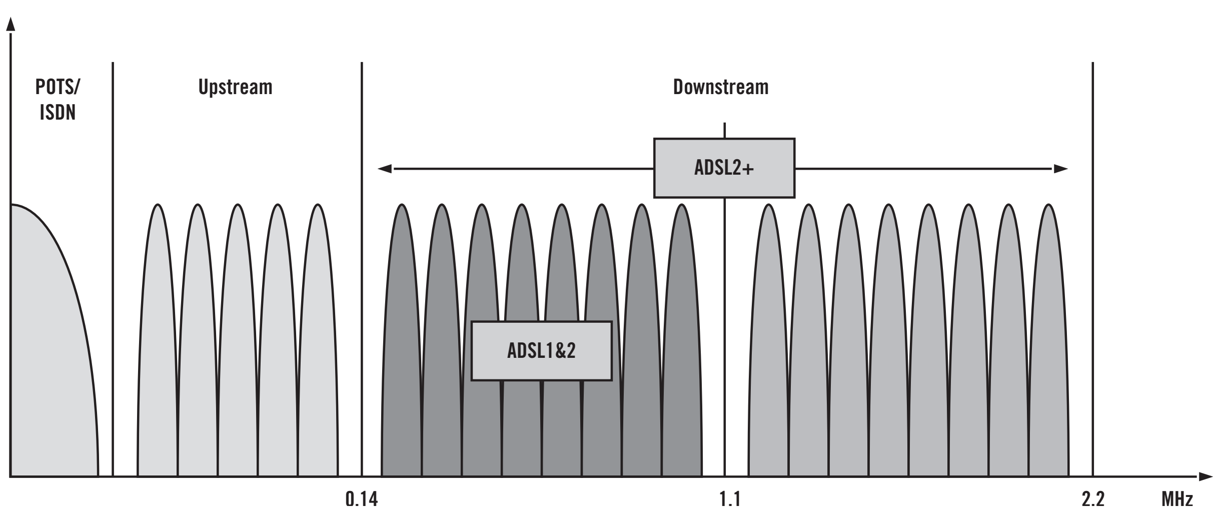

Figure 2. The frequency spectrum for ADSL/2/2+.

ADSL2 has been specifically designed to improve the data rate and reach of ADSL largely by achieving better performance on long lines. ADSL2 accomplishes this by improving modulation efficiency, reducing framing overhead, achieving higher coding gain, improving the initialization state machine, and providing enhanced signal processing algorithms. ADSL2+ further improves on the ADSL2 standard by allocating a larger spectrum for downstream data, dramatically improving the data rate over ADSL2 or ADSL (Figure 3).

This increased bandwidth allows for service providers to deliver high-definition television, voice service, and high-speed Internet in one bundled package. The option to provide these triple play services or to provide DSL to customers farther from the central office comes at a cost, however. The higher frequencies used by ADSL2+ are affected by cable faults that would not impede traditional ADSL. Also, as residential customers begin to rely on ADSL to provide not only their Internet connection, but also telephone service and television, they are much more sensitive to service interruptions. These factors make adequate copper testing for ADSL2+ crucial.

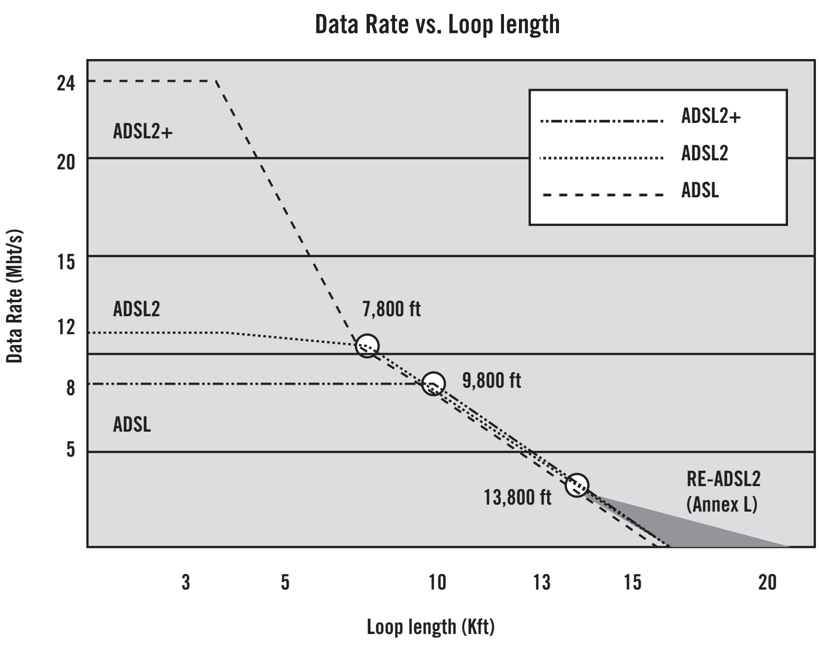

Figure 3. Data rate and loop length reach improvements for ADSL/2/2+.

Test the Copper

The health of the copper pair is very important for ADSL. Since it shares the loop with POTS, qualifying or troubleshooting a line for ADSL builds upon the traditional tests performed for a line carrying only POTS. However, because of the high frequency signal of ADSL, some faults that do not affect telephone service can render the loop unacceptable for ADSL. For information regarding POTS testing, refer to the gray box on the right.

Foreign Voltage

Testing for the presence of foreign voltage on an open pair should be done before any other tests. Excessive foreign voltage on an open pair is a sign that the loop is in poor health. It can also be a safety hazard.

Foreign DC Voltage

An open pair can have DC voltage on it from other services in the same cable group, such as POTS, T1, ADSL, or HDSL. This happens when a pair is crossed with one or more working pairs as a result of physical cable damage, water in the cable, or faulty splices. This cable damage can result in noise or attenuation on an ADSL circuit.

To accurately test for DC voltage, use a high-impedance digital voltmeter (1 MΩ termination) and test on a dry pair, with the circuit open on the far end. Ideally, an open pair should have no DC voltage, but ADSL can tolerate some amount of DC voltage, generally less than 3 V DC tip to ring, tip to ground, and ring to ground is considered acceptable.

If a DC voltage measurement is performed on a wet pair connected to the central office, there should be between 48 V and 52 V DC tip to ring, -48 V to -52 V DC ring to ground, and less than 3 V tip to ground.

Foreign AC Voltage

Induction from nearby power lines or interference from other data services in the same binder can cause an open pair to have AC voltage on it. This AC voltage acts as a noise source, degrading the quality of ADSL transmission.

Power line inductance is called power influence and is caused by power lines in close proximity to the loop. Power influence usually originates from power lines that share poles or are buried underground near the telephone cable, but power influence can also originate from lines that are anywhere within a few thousand feet of telephone cables. The length in which the telephone cables run parallel to the power lines has a greater effect on power influence than their proximity to each other.

To measure foreign AC voltage, use a digital voltmeter. Typically, the tip to ring voltage should be less than 3 V AC and the tip to ground and ring to ground voltages should be less than 10 V AC. Advanced copper measurement test sets can also measure power influence in dBrnC. An acceptable level of power influence is anything under 80 dBrnC, while 80 to 90 dBrnC is considered marginal. Greater than 90 dBrnC is unacceptable.

Typical POTS Testing

A POTS loop requires that several parameters be met in order to provide good service to the customer: Good DC continuity, Adequate loop current, Low loop loss, Low noise.

Therefore, testing for POTS requires accurate measurement of these parameters and the ability to locate faults that could lead to service impairments.

DC Current

On a good loop in the on-hook state, there should be no DC path between the three conductors of a POTS loop (tip, ring, and ground). Specifically, there must be at least 3.5 MΩ of resistance between each conductor. If less than 3.5 MΩ of resistance is measured between the tip and ring, a short exists. If less than 3.5 MΩ of resistance is measured between the tip and ground or the ring and ground, a ground fault exists. These faults may be found using either a time domain reflectometer (TDR) or a resistive fault locator (RFL).

Loop Current

The current running on a POTS loop provides the power to the customer's telephone and keeps the loop clean by burning off excess condensation and corrosion within the spice points. To adequately provide both functions, the loop current should be at least 23 mA at the customer's network interface device. If this measurement is too low, the common cause is that the loop is too long, or there is a resistive fault. If no loop current is measured, the loop is probably open at some point.

Loop Loss

The loop loss measurement can be used to ensure that voice or data transmission can be sent reliably on the loop. This is accomplished by dialing the local switch's milliwatt number and requesting that a tone be sent, which is then measured at the customer's residence. The loop loss should be less than 8 dB at 1,004 Hz.

A more thorough loop loss measurement can be performed by testing the loss at 3 tones (404 Hz, 1,004 Hz, and 2,804 Hz), 10 tones, 17 tones, or 23 tones. These sweeps may identify AC faults, such as bridged taps, excessive loop length, misplaced load coils, and wet sections.

Noise

Metallic noise consists of unwanted voltage that exists between the tip and ring on the loop. If this voltage is greater than 20 dBrnC, it can be heard on the phone as a crackle or hum. If the voltage is greater than 40 dBrnC, the loop is unusable. Noise is a symptom of a poorly balanced pair or excessive power influence. If the power influence is greater than 80 dBrnC or if the balance is less than 60 dB, the loop may have audible noise.

Loop Length

Capacitance and attenuation of a loop increases as the loop length increases. If the loop is too long, the modems may not synchronize at all, or they may have a low data rate. Therefore, there is a maximum length for a pair in order to be acceptable for ADSL, depending on wire gauge, gauge changes, and overall line condition. ADSL/2/2+ is designed to support loop lengths of up to 18,000 feet. To take advantage of the rate increases available with ADSL2+, though, the loop length must be less than 8,000 feet.

To test loop length, use an opens meter on a disconnected pair. Since cable specifications require that all wiring used for the outside plant have a constant capacitance of .083 μF per mile between the tip and ring, an opens meter can measure the capacitance to the open and convert the measurement to distance. The capacitance between the tip and ground or the ring and ground, however, is dependent upon the cable fill type. Consequently, to accurately measure opens tip to ground or ring to ground, the test set must be configured for the proper fill type. Since bridged taps add capacitance to all opens measurements, this length includes any bridged taps.

Loop length can also be measured by placing a short on the far end and then taking a distance to short measurement. This measures the resistance of the loop and will not include the length of the bridged taps. Resistance is dependant upon both cable gauge and temperature, so these values must be set for a test set to accurately determine resistive length.

Balance

A balance measurement is a great method to qualify the overall health of the pair. Theoretically, the tip and ring conductors should have the same electrical characteristics. The more alike the conductors are, the better the pair is at rejecting noise, both internal (inside the binder) and external. A balance measurement quantifies the amount of similarity. If a pair is out of balance, it will not reject noise very well and will either affect the data rate of ADSL or will prevent synchronization entirely.

Longitudinal Balance

The most effective way to measure balance is by exciting the pair with a signal and measuring the response difference between the tip and ring. The measurement is given in decibels, with 60 dB or greater generally considered acceptable, 50 to 60 dB marginal, and less than 50 dB unacceptable.

Balance can also be derived by subtracting the noise level from the power influence level. To accurately measure balance using this method, the power influence must be at least 70 dB.

Resistive Balance

Balance can also be measured using a resistive measurement by grounding both conductors at the far end and comparing tip to ground and ring to ground measurements. These measurements should be within 5 Ω or 1% of each other, whichever is less. This measurement requires action at the far end; therefore, a longitudinal balance measurement is usually preferred.

Capacitive Balance

Another method to compare the similarity between the tip and ring is with an opens meter. If you measure the loop length of an open pair, the tip to ground measurement should be within 1% of the ring to ground measurement. Since this measurement is a direct conversion from the capacitance, if it falls outside of 1%, this mismatch can point to faults on one of the conductors.

Leakage Resistance

An open loop should have no electrical path between the tip to ring, ring to ground, or tip to ground. Cable damage, wet sections, or bad splices can create a resistive path for current to flow. Minor resistive faults affect the balance of a pair, leading to noise. Major resistive faults create a hard short on the circuit and a complete signal loss.

To identify resistive faults, use a digital ohmmeter. When conducting this test, it is important to simulate conditions that will exist on the line when it is turned up for service. This will help to ensure that the stresses applied by the working line will not affect the pair condition. It is, therefore, important to take these measurements with an ohmmeter that is specifically designed to measure cable pair insulation resistance. In general, a resistance greater than 3.5 MΩ is considered acceptable for ADSL.

To locate faults, use a resistive fault locator (RFL). An RFL requires a known good wire to use as a reference. This can be the other wire in the pair or both wires of a separate pair. For a single pair measurement, the far end tip and ring must be shorted together. For a separate pair measurement, the tip and ring of the good pair must be shorted to the faulted wire of the bad pair. The accuracy of an RFL depends on correctly setting the cable gauge and temperature, as this affects resistance.

Load Coils

The quality of voice calls is degraded by the capacitance on a very long loop (greater than 18,000 ft). The attenuation caused by this capacitance can be counteracted by adding inductance to the line, in the form of load coils. Load coils are typically spaced 6,000 feet apart and 3,000 feet from each end, but may be more or less depending on the loading scheme used.

Load coils act as a low pass filter, causing very high attenuation for signals above 4 kHz. This attenuation is too great for ADSL signals, so any loads on a loop intended to carry ADSL must be removed. This includes loads on bridged taps.

A simple way to check for load coils is with a load coil counter. A load coil counter sends a frequency sweep to find the attenuation characteristic of a load coil. It then returns the number of loads on the line. These test sets often require that there be at least 1000 feet of line after each load in order to detect the load's presence.

To identify the location of load coils, a time domain reflectometer (TDR) can be used. A load coil shows up on a TDR like an open – an upward spike (Figure 4). The leading edge of the spike can be used to approximate the distance to the load. A TDR can only accurately show the distance to the first load. Therefore, if there is more than one load coil, a new TDR trace should be made after each load is removed.

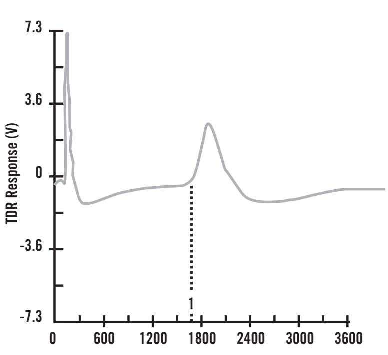

Figure 4. A TDR trace of a load coil.

Bridged Taps

Bridged taps, or laterals, are excess lengths of wire that extend past the subscriber or are spliced in along the span. They do not interfere with normal POTS service and may exist due to moved equipment or plans for multiple termination points.

Bridged taps, however, degrade the performance of an ADSL circuit by causing signal reflections at the splice point and at the end of the tap. These reflections can cause errors. Bridged taps also add noise to the circuit by acting as antennas, picking up external noise along the tap, and attenuate the signal at the wavelength that corresponds to the tap length.

ADSL modems can tolerate some level of noise and attenuation, so some bridged taps are acceptable. As the length of taps increases, however, this noise and attenuation will render the loop unacceptable for ADSL.

The length of all bridged taps on the span should total less than 2,500 feet with no single tap exceeding 2,000 feet. For instance, eight 60-foot taps are acceptable, but one 2,400-foot tap is unacceptable. The exception to this guideline, however, is that no bridged taps should be placed within 1,000 feet of either ATU. The closer the bridged tap is to the ATU, the higher the energy of the reflected signals. If the tap is too close, the reflection may contain more energy than the signal from the other ATU. At this point, the circuitry is unable to distinguish between data and unwanted reflections.

The most effective way to test for the presence of bridged taps is with a TDR. The impedance of a bridged tap shows up on a TDR trace as a downward spike followed by an upward spike (Figure 5). The beginning of the downward spike gives the approximate location of the tap's splice point. The distance between the lowest point and highest point gives the approximate length of the tap.

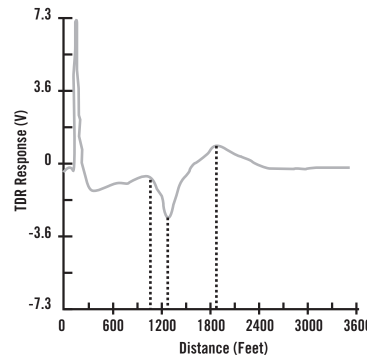

Figure 5. A TDR trace of a bridged tap.

Bridged taps can also be identified by measuring the capacitive loop length and comparing it to the resistive loop length. Since bridged taps act as extra capacitance, the capacitive loop length will include the length of any bridged taps, while the resistive loop length will not. This is a two-ended test, requiring that the line be open for the capacitance measurement and then shorted for the resistive measurement. It is not as simple as a TDR trace, nor does it give you the location of each tap.

Noise

On a POTS line, noise in the frequency range below 4 kHz is a problem because it is audible. The buzzing, static, clicking, or popping sounds can drown out the speaker's voice if above a certain threshold. In the same way, the ADSL message is lost if high frequency noise reaches a threshold. This results in bit errors or complete loss of synchronization between the ATU-R and ATU-C.

Noise can be caused by the following conditions:

- Electromechanical devices near the circuit, such as relays
- Environmental influences, such as lightning
- AC signals, such as those generated by power sources at 60 Hz (power influence)
- Other adjacent pairs carrying services, such as T1 (crosstalk)
- Unbalanced pairs

To measure noise, use a test set with wideband noise measurements – as opposed to voice-band noise measurements. To filter only for noise that will affect ADSL, set the test set to use a "G Filter." Also, the far end should be terminated with a 100Ω resistance for any noise measurement. Wideband noise is measured in dBm and is usually a number below zero. For ADSL, the maximum noise depends on the attenuation and the desired line rate.

Environmental influences and electromechanical devices can cause spikes of noise that are not continuously present. This is called impulse noise. To measure impulse noise, use a test set that can count noise spikes over an extended time frame. This will increment a counter for every instance that the noise crosses a user-defined threshold.

A spectrum analyzer can help troubleshoot noise problems by showing a graph of where noise disturbers exist on the spectrum (Figure 6). For example, suppose that a T1 service in the same binder group is interfering with the ADSL. A spectrum analyzer will show the noise pattern on the line and will allow you to overlay a mask of the frequency characteristics of the T1. If the characteristics match up with the noise on the circuit, then the interferer can be determined to be the T1. This is typically a troubleshooting test rather than a turn-up test.

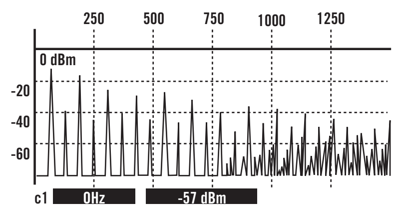

Figure 6. A noise pattern on a spectrum analyzer.

The most effective way to measure noise, however, is by emulating an ADSL modem and synchronizing it to the DSLAM. If the circuit is in good enough health to support synchronization, this test set can then provide detailed statistics about the line. A high noise margin indicates that the loop can sustain additional noise while maintaining a good connection. A bits per tone graph will show if there are parts of the ADSL spectrum that are going unused by the modem due to excessive noise at those frequencies (Figure 7).

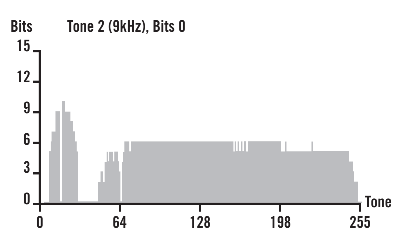

Figure 7. A bits per tone graph for a good ADSL circuit.

Quick Guide

Foreign Voltage

	Tip to Ring	Tip to Ground	Ring to Ground
DC Volts	<3 V	<3 V	<3 V
AC Volts	<3 V	<10 V	<10 V

Loop Length <18,000 ft

Balance

Longitudinal	>60 dB
Resistive	<5 _ or <1%
Capacitive	<1%

Leakage Resistance >3.5 MΩ

Load Coils none

Bridged Taps

Total length	<2500 ft
Single tap length	<2000 ft
Distance from ATU-C or -R	>1000 ft

Worldwide Headquarters

One Milestone Center Court
Germantown, Maryland
20876-7100
USA

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Regional Sales Headquarters

North America
One Milestone Center Court
Germantown, Maryland
20876-7100
USA
Toll Free: 1 866 ACTERNA
Toll Free: 1 866 228 3762
Tel: +1 301 353 1560 x 2850
Fax: +1 301 353 9216

Latin America
Acterna do Brasil Ltda.
Av. Eng. Luis Carlos Berrini
936 9th Floor
04571-000 São Paulo
SP-Brazil
Tel: +55 11 5503 3800
Fax:+55 11 5505 1598

Asia Pacific
Acterna Hong Kong Ltd.
Suite 4010, 40th Floor
China Resources Building
26 Harbour Road
Wanchai
Hong Kong
Tel: +852 2892 0990
Fax:+852 2892 0770

Europe, Middle East & Africa
Acterna Germany GmbH
Mühleweg 5
72800 Eningen u.A.
Germany
Tel: +49 7121 86 2222
Fax:+49 7121 86 1222

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