Capturing and Analyzing Impulse Noise

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Impulse noise is not new to the outside plant (OSP) and customer premises. What is new is the fact that the latest high-speed DSL technologies (such as VDSL2) typically operate at critical SNR margins, use a much broader part of the frequency spectrum and are more susceptible to impulse noise than legacy voice or ADSL.

The properties of impulse noise are what make it such a challenge for broadband service providers. It is intermittent by nature, more difficult to detect and analyze than traditional interference, and tends to defy traditional plant troubleshooting methods. While the ultimate goal is to mitigate its effects, the first steps are to detect, capture and analyze it to determine the best course of action.

IMPULSE SOURCES AND CHARACTER

Broadband service providers are concerned with three categories of impulse noise. They are shown in figures 1, 2 and 3.

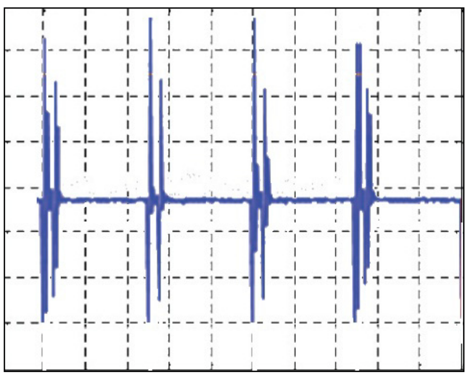


Figure 1. Repetitive Electrical Impulse Noise (REIN)

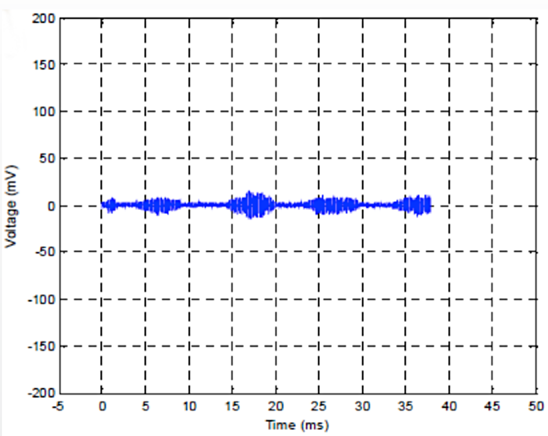


Figure 2. Single High Impulse Noise Event (SHINE: >10 ms non-repeating)

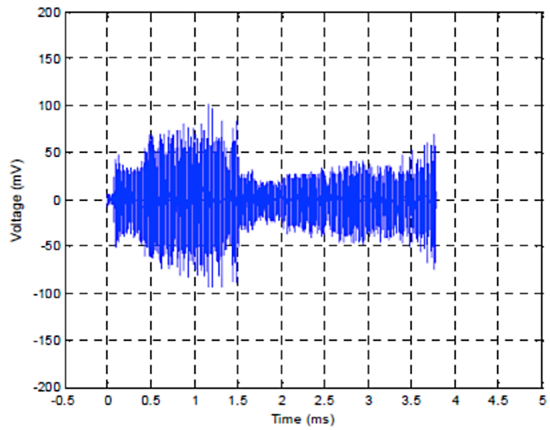


Figure 3. Prolonged Electrical Impulse Noise (PEIN: 1-10 ms non-repeating)

Repetitive impulse noise (REIN) sources tend to be related to electrical generation and conversion, such as power supplies. When active, they tend to emit a constant signal that can significantly impact DSL rates, SNR margins, error rates, and even lead to loss of sync. Short high impulse noise events (SHINE), while intermittent, may have a major impact on DSL circuits and often cause them to fail and lose sync. Prolonged impulse noise (PEIN) sources are generally not as severe as SHINEs, but they tend to have long pulses (2 ms - 10 ms) that can lead to data loss, high error counts and distorted TV/video signals.

A new fourth category should also be considered: electromagnetic interference (EMI). This is interference from non-telecom sources such as transformers, power supplies and electrical motors located on or near the premises.

HIGH-SPEED DSL SIGNALS

At first, legacy voice was mainly concerned with REIN and SHINE from power/main distribution systems. When DSL technology was implemented, these effects were minimized because DSL includes error correction techniques and operates at frequency ranges well above typical power distribution signals. In some cases, imbalanced or defective power/main lines emit harmonics into ADSL upstream frequency bands as well as some downstream bands. Fortunately, DSL is able to mitigate these harmonics with built-in protection mechanisms like Reed-Solomon error correction, forward error correction (FEC) and impulse noise protection (INP).

As the race for broadband rages on, DSL technology is moving more and more towards very high data rates. These high-frequency DSL signals are being transmitted via the OSP, well beyond the network interface device (NID) or the demarcation point (outside line connection or inside wall plate) into noisy premises environments in order to feed gateways, routers and ultimately, set-top boxes. Many premises noises, especially impulse noises and EMI, occur in high-frequency ranges, conflicting with DSL signals. They were of little concern to POTS and low-speed Internet connections because of retransmission schemes that were effective for file download and chat.

Today, VDSL2 uses frequencies ranging from 100s of kHz to 30 MHz to achieve data rates as high as 100 Mbit/s on a single pair. Unfortunately, this technology can tolerate little interference because performance margins are critical. Interference causes data and packet loss, and impacts sensitive services such as video (resulting in poor quality of experience for customers).

BUILT-IN DSL IMPULSE NOISE MITIGATION (G.INP)

The latest DSL technologies now have built-in impulse noise mitigation, most notably, ITU impulse noise protection or G.INP (G references the ITU standards body). Other vendor-specific implementations have been around for several years, such as Broadcom PhyR™, but G.INP is now supported in nearly all CPE and DSLAM line cards.

Historically, impulse noise protection was an important weapon in the battle against impulse noise. However, since INP reduces the data rate, it is important to use it only where the severity of the noise requires it (per circuit basis). Better is the new G.INP, which should be employed because it has a much smaller impact on service. In fact, a low level might be recommended for all DSL circuits, especially for customers who like to watch Netflix™, Hulu™ and online videos. In general, higher levels of G.INP should only be used when the stability of the circuit requires it.

ADSL2+ and VDSL2 service providers should talk to their DSLAM/remote supplier about G.INP and how to use it, since this may stabilize a circuit without rework or grooming.

WHY TRADITIONAL PLANT TROUBLESHOOTING DOESN'T WORK

According to Sherlock Holmes, "Once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth."

All operators should attempt to quickly confirm or rule out impulse noise as the culprit. Unfortunately, since impulse noise detection tools are rare in the first line technician's toolkit, they will more often than not spend hours focusing on typical issues: metallic pair faults, shield quality, or crosstalk (XTALK). Once out of ideas, the trouble then likely becomes chronic with no obvious resolution in sight, even for experts.

This is when operators might turn their attention to non-continuous sources of noise. However, this can be a monumental challenge, especially when you consider that the following premises equipment have been known to overlap and interfere with DSL:

- Any device with an earth leakage/ground fault
- Central heating, air conditioning, immersion heaters or any device with a faulty thermostat
- Power supply units for PCs, routers, TVs, phone systems, monitors, etc.
- Large machinery or industrial/commercial power usage
- Electric Christmas tree lights
- Security systems
- Satellite TV/decoders and other digital television services
- DVD appliances
- Electric fences

These emitters are very difficult to detect and isolate because they do not have typical telecom signals and are usually intermittent.

Impulse noise is usually considered after all other, more common issues have been eliminated. It would certainly save a great amount of time and trouble to detect and characterize, or rule out, the presence of impulsive/EMI noise earlier in the troubleshooting process.

IMPULSE NOISE DETECTION

Detecting impulses is difficult because their speed and frequency distribution often fly under the radar of typical wideband spectral noise meters used in the field. Moreover, three different types of impulses affect broadband transmission: repetitive (REIN), prolonged (PEIN) and single (SHINE). Similar to an oscilloscope, a test tool that can see and display impulses as a function of time is needed. The scope will make them visible, either in a continuous scope view or in a "trigger" mode, which captures single events or sub-pulses. Many events are comprised of multiple sub-pulses or trains (figure 4), which can be made visible with a scope-type test tool.

To capture and analyze impuse noises, a test tool requires:

- Very fast voltage trigger
- Very fast signal processing to see fast repetitive pulses
- Minimum dead time (time the system requires before it can measure the next impulse)
- Frequency component view (does it overlap DSL and other service passbands?)

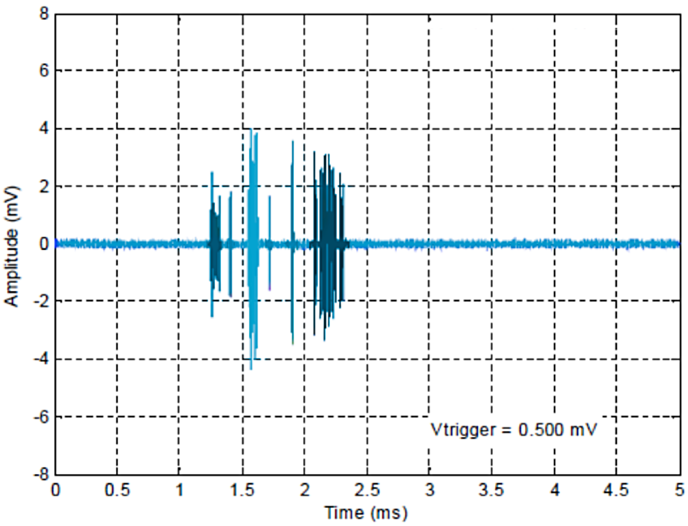


Figure 4. Impulse event consisting of several sub-pulses

IMPULSE ANALYSIS

The ultimate goal of impulse noise analysis is to counter the emitter/source. Working knowledge of the following characteristics is key to selecting the appropriate countermeasures:

- Repetitive or single impulse event
- Pulse length (time from start of first sub-pulse to end of last sub-pulse)
- Pulse count over time (how many separate pulses)
- Interpulse duration
- Peak voltage/level
- Background noise level
- Crest factor or amplitude of the event relative to the background noise
- Disruption time (cumulative duration of all sub-pulses in a time period)
- Frequency spectrum distribution (does the energy overlap broadband signals such as VDSL2 and ADSL2+?)

Mitigation efforts will be determined by whether the impulse noise is repetitive (REIN), prolonged (PEIN) or single (SHINE).

Repetitive sources tend to be related to power distribution, whether electrical mains, electric motors or power supplies, which are used in most continuously operating sources like electronic devices, exercise equipment, electric fences, etc. They will cause a significant, continuous disruption and require immediate resolution!

Non-repetitive events tend to disrupt service, but only temporarily. Understanding the duration is critical, since a short, fast, single pulse, such as from a handheld drill motor (see graph below) may cause errors that G.INP may be unable to compensate for. On the other hand, a long pulse that is more than ten milliseconds long, is likely to crash the modem.

The level of an impulse is also important because some are too low to affect service. It is recommended to focus on those that far exceed background noise, causing data/packet loss or service failure.

Time Domain Graph:

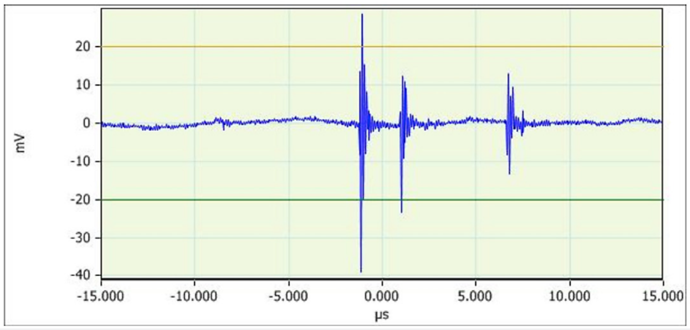
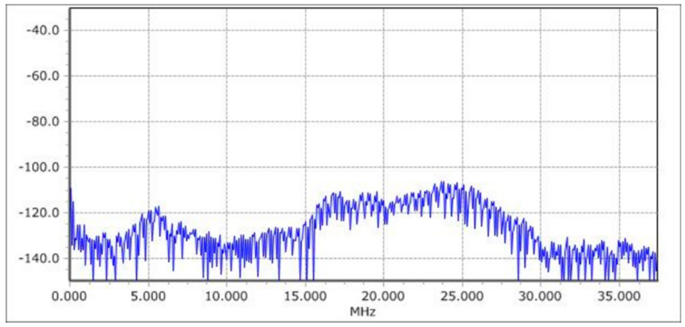


Figure 5. Time domain example of start of handheld drill

Frequency Domain Graph:



MITIGATION OPTIONS

The purpose of this document is not to provide expert advice on how to mitigate impulse sources. However, based on an understanding of the nature and typical sources of EMI (versus more historical REIN), the following actions are recommended:

1. Inspect the ground/earth of the OSP (shield/sheath).
2. Check the ground/earth at the NID/demark (should be less than 25 ohms, and ideally equal with the power system ground; a differential here can induce unwanted currents on the telephone pairs).
3. Make sure bonds and service access interface earth/grounds are clean and solid to the premises.
4. Ensure the circuit has adequate wideband longitudinal balance.
5. Put the modem/gateway as close to the NID/demark as possible (better signal level).
6. Bypass the existing twisted pair inside wiring (IW) and use a CAT5 or higher network cable (which is more immune to interference) direct to the CPE.
7. Isolate only one pair of the IW to the CPE and disconnect any other loops, extensions and connectors (keeping in mind IW is not shielded and has marginal twist and noise immunity, and is more susceptible to noise).
8. Move the CPE modem/gateway away from possible impulse emitters (power falls off rapidly with distance).
9. Turn off emitting sources when not in use.
10. Replace emitting sources.

CONCLUSION

Non-traditional, hard-to-detect impulse noise and EMI may be the source of chronic troubles when no other cause is apparent. Isolating them requires a different approach to testing as well as some specialized test tools. The ability to capture, analyze and characterize them in the time domain as well as in terms of frequency will guide you to appropriate mitigation techniques and ensuring happier customers!

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