INVENTION DISCLOSURE

1. **Invention Title.**

Methodology for Localizing Additive Upstream Impairments on CATV Networks

2. **Invention Summary.**

This invention disclosure, defines a methodology to localize additive upstream impairments on CATV networks using granular time and frequency domain analysis of impairments in conjunction with pre-equalization data.

3. **Invention Description**.

a. **Describe the invention in detail and/or attach a description, drawing(s) and/or diagram(s), if available.**

The attached file "DisclosureAdditiveUsImpairmentsFaultLocalization.doc" describes the details of this invention disclosure

b. **Why was the invention developed? What problem(s) does the invention solve? How is it better?**

It provides with the capability to localize additive impairments in the CATV network. This saves time and cost to repair plant problems, improves reliability and enables the provisioning of advanced services.

To the best of my knowledge no process exist to remotely resolve the location of additive impairments like impulses or narrowband interferers. The systems that exist (CPD Hunter) performing similar function require use of instrumentation in the field. The process described in this disclosure requires only instrumentation in the headend or hub in addition to equalization data gathered remotely from CMs in the field.

c. **Briefly outline the potential commercial value and customers of the invention.**

Plant maintenance cost reduction, reduced churn, performance improvement. Customers would be the cable operators as well as operation systems developers and plant maintenance instrumentation vendors.

4. HOW is your invention different from existing products, processes, systems?

Not aware of existing products, processes or systems that does what is being described with this invention. As mentioned earlier CPD Hunter from Arcom covers a subset of this functionality but using instrumentation in the field.

Methodology for Localizing Additive Upstream Impairments on CATV Networks

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This invention disclosure, defines a methodology to localize additive upstream impairments on CATV networks using granular time and frequency domain analysis of impairments in conjunction with pre-equalization data.

Summary

This additive impairment localization methodology relies on the identification of the distortions characteristics that are present on the different upstream paths in a fiber node using CM pre-equalization coefficients. Signals transiting upstream paths that have a micro-reflection, are subjected to a distortion generated from the interference of the main signal with attenuated and delayed copies of this main signal. Just as signals that are generated by CMs are distorted, so are additive impairment signals which are generated through ingress or malfunctioning devices in the CATV network. The distortion characteristics that an impairment signal suffers should match one or more distortion characteristics obtained from CMs equalization data. Instrumentation suitable to analyze the impairments with high time and frequency granularity such as a vector signal analyzer, is used to determine the attenuation and delay characteristics after special analysis. The correlation of the impairment signals' delay/amplitude signatures with those obtained from the pre-equalization coefficients allow to localize the impedance mismatches that corresponded to the additive impairment.

Additive Impairments

The two main additive impairments that exist in the CATV environment are impulse noise or burst noise and narrowband interferers. In many cases these impairments are generated outside the CATV network but through plant defects, mis-configurations or other problems, these signals enter the coaxial cable network. This is known as ingress. In some cases, the additive impairments can also be generated through problems that occur within the cable network. In most cases the presence of such impairments is associated with an impedance mismatch. For example a crack in the cable through which a narrowband interferer or impulses leak into the cable network represents an impedance discontinuity or impedance mismatch (a basic ingredient of a micro-reflection). A second example would be when a center conductor is corroded and causes common path distortion (CPD). This corrosion not only causes narrowband interferer signals customary of CPD but they also represent an impedance discontinuity.

Impulse Noise

Impulses in cable networks can have many origins. It can be generated through arcing, sparking, lightning, signal beating, motors in the home etc. They are short in duration (typically less than 20 microseconds) but they are very wide in frequency (they can fully cover the US spectrum). Figure 1 shows a spectral view of an impulse.

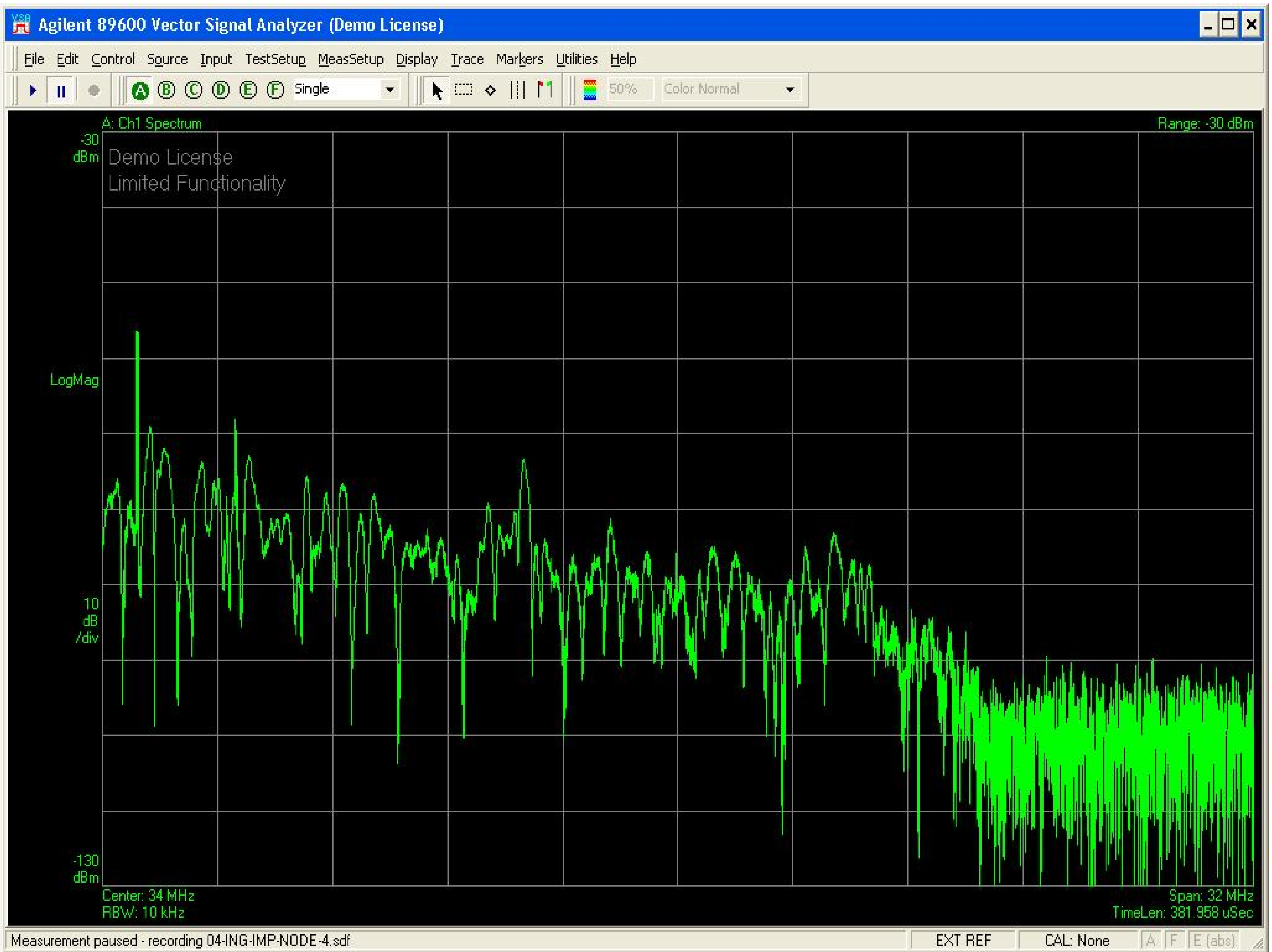

Figure 1 – Upstream Spectrum Capture Showing Impulse

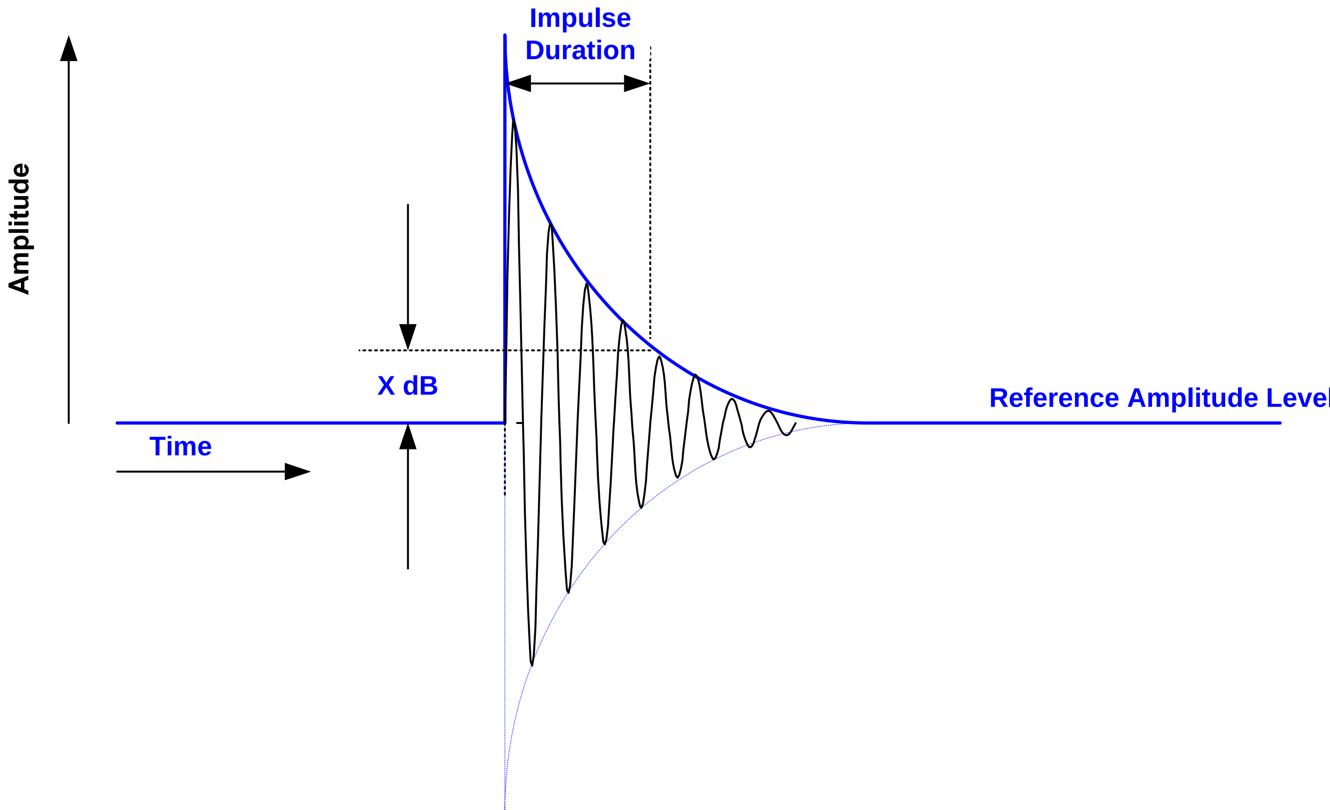

Figure 2 – Time Domain Representation of Typical Impulse

Impulse Characterization

The key parameters in characterizing impulses are the power level or amplitude, its duration, as well its repetition rate. Figure 3 shows an impulse example measured in the time and frequency domains. They exhibit their characteristic wideband nature and in the time domain, the typical exponential decay.

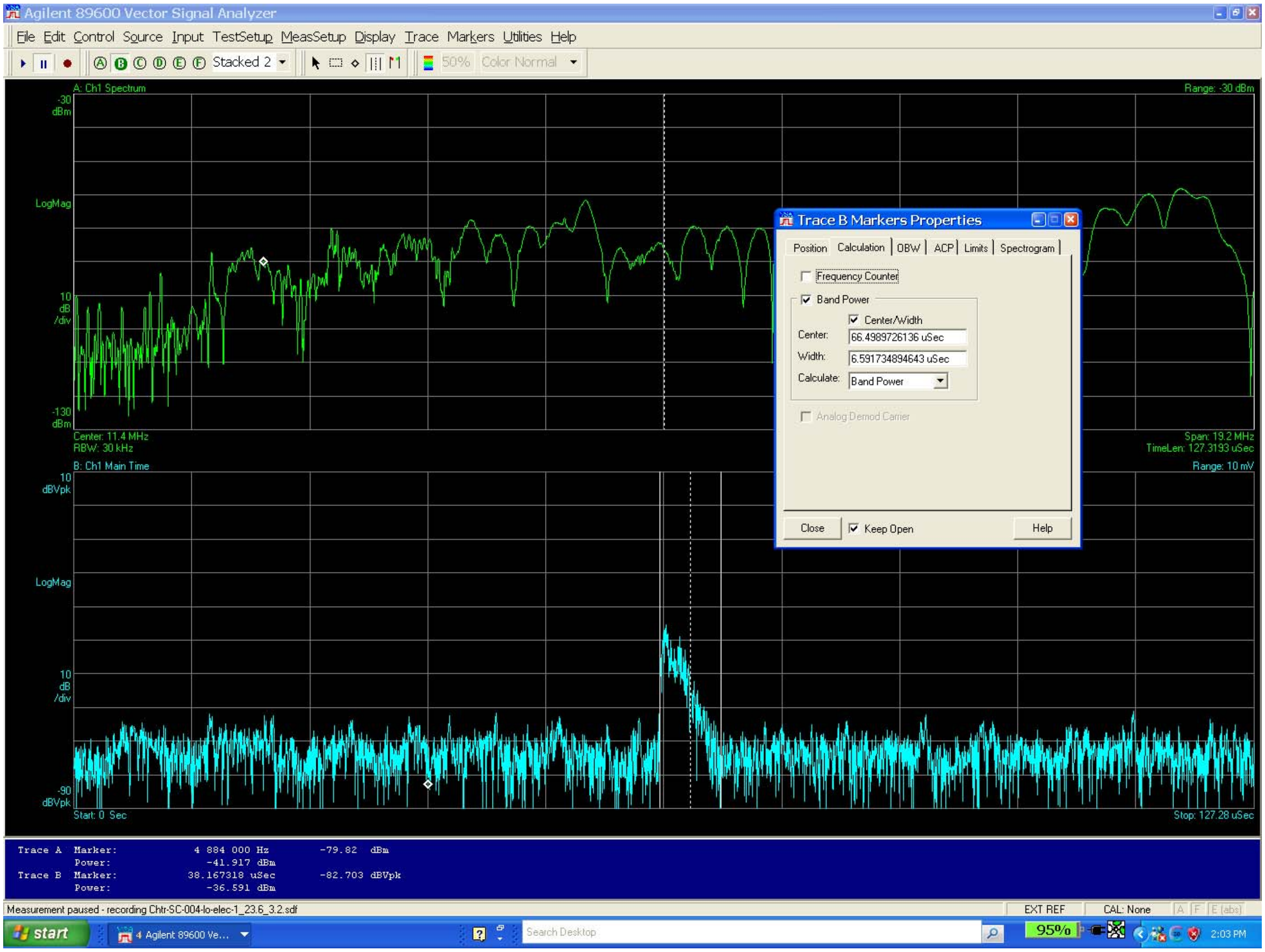

Figure 3 - Typical Impulse in time and frequency

Figure 4 shows the impulse duration statistics over a large number of nodes. From a duration perspective it can be observed that most impulses have a duration that lasts typically less than 10 microseconds.

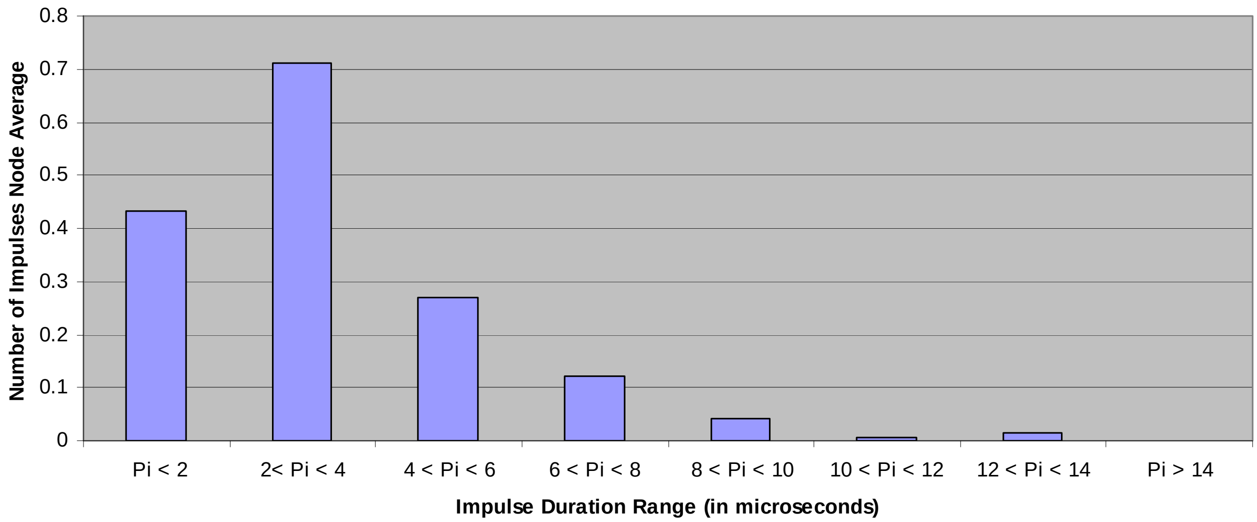

Figure 4 - Impulse Duration Characteristics

Narrowband Interferers

Narrowband interferers can be due to external sources such as amateur radio signals or citizen band signal, shortwave radio etc. They can also be caused by effects internal to the network such as common path distortion. They are typically very narrow in frequency and for the most part they are fairly static in time or changing slowly in time.

General Approach

Detail knowledge of the impairment characteristics will be used to determine how the impairment looks like before and after traversing the linear distortion portion of the network

A cable operator will fully characterize the distortion in a fiber node by collecting upstream path distortion data through the collection of the CM pre-equalization coefficients. It is assumed that some of these linear distortions modify the additive impairment.

Figure 5 shows a fiber node with a few linear impairments. If you have an additive impairment that originates in a localized portion of the network it will traverse a series of upstream impairments that “mark” or “modify” this impairment, where the impairment signature (for example amplitude and delay) is the one that uniquely modifies this impairment. The CMTS typically has tools with limited time and frequency resolution tools that could be for this type of analysis. Therefore instrumentation like a vector signal analyzer is used for this high resolution characterization of impairments. In the case of a narrowband interferer, which can be approximated to a CW in the frequency domain, time domain analysis of this CW signal has to be analyzed. In the case of an impulse, which in the absence of distortion in its path could be approximated to a flat (at least piecewise) wideband signal would have to be analyzed in the frequency domain for the instant when the impulse occurred.

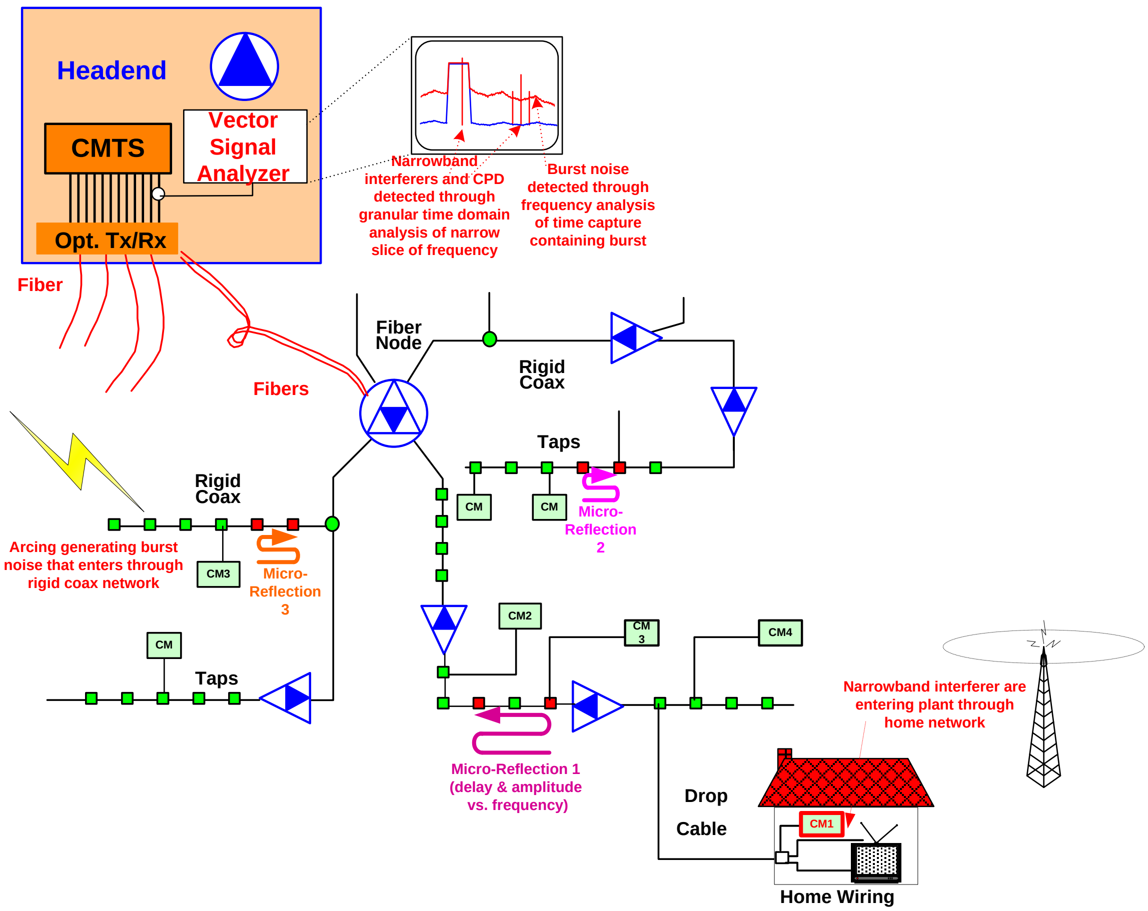

Figure 5 Fiber node with linear impairments

Impairment Modification or Marking

An impulse signal that is very broad in spectrum and at least piecewise constant (flat) will change in frequency response depending whether this locally generated signal traverses a distorted upstream path or not. Figure 6 shows how the distorted signal has a ripple and a periodicity that can be used to extract the micro-reflection signature.

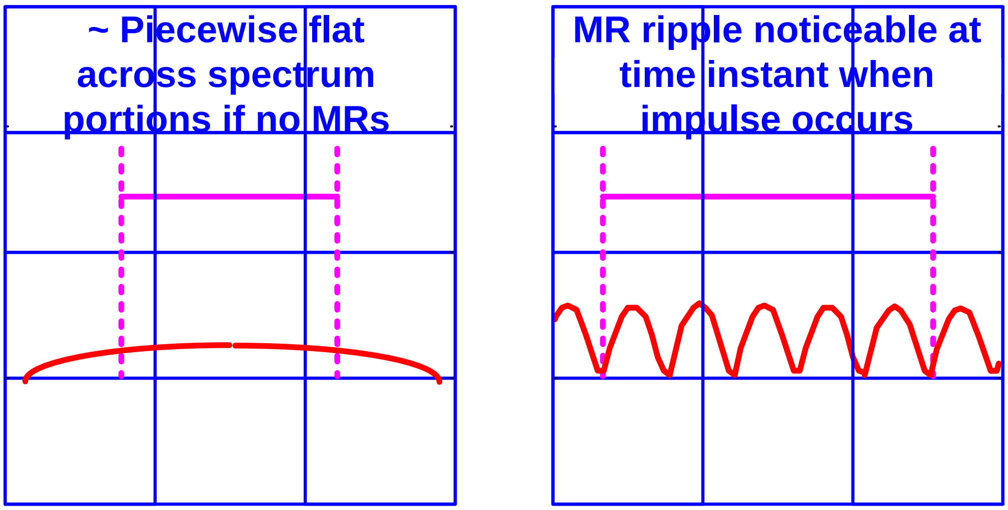

Figure 6 Frequency view of impulse noise affected by micro-reflection

For the narrowband interferers the analysis of the portion of spectrum occupied by the interferer would have to be done in the time domain. There is a way of estimating the micro-reflection level by looking at the peak and valley delta of its envelope

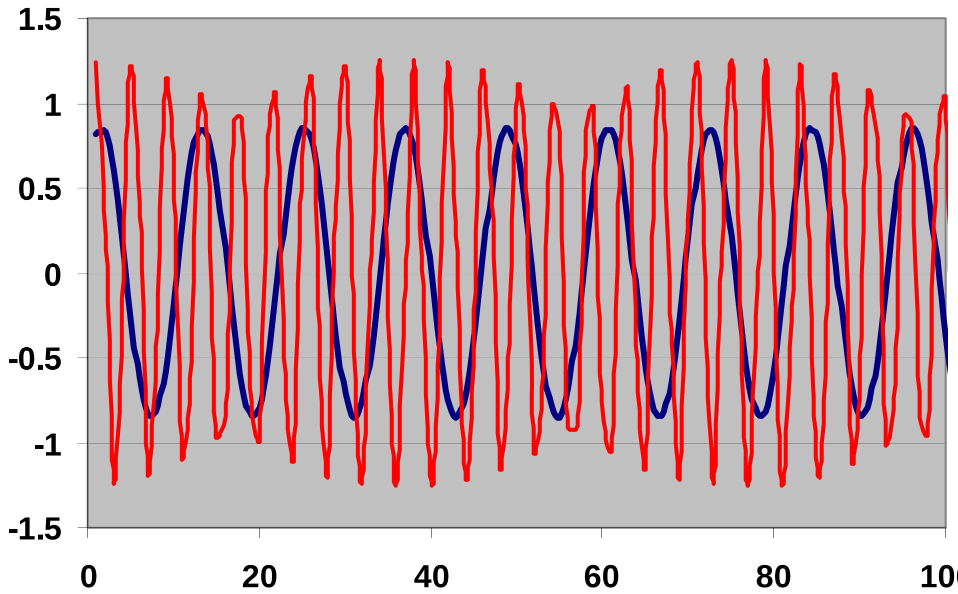

Figure 7 Time view of narrowband interferers affected by micro-reflection

Impulse Noise Localization Process

- Gather pre-equalization data from node and determine different upstream path signatures.
- Use vector signal analyzer (VSA) to collect snapshot of spectrum at the moment (time slice) when the impulse occurred (reached peak value).
    - Impulse is very short in duration so it will be wide in spectrum and can be approximated to a constant value over a portion of spectrum.
- Using VSA, analyze ripples and the peak to peak or valley to valley frequency spacing to determine the delay/amplitude signature of impairment.
- Compare impairment distortion (i.e. delay/amplitude) signature with distortion signature (i.e. delay/amplitude) signatures of CMs.
- Source of impulse is located in portion of the plant between CMs that share signature and CMs that don't share signature.

(In Figure 5 an additive impairment that originates in the home of CM1, will be marked by micro-reflection #1. Through topology correlation you know it cannot be located north of CM2. If in addition to the structural micro-reflection there are home distortions affecting the additive impairment you will be able to determine the home from which the impairment originated. If the impairment distortions doesn't home distortions that are detectable through correlation of home distortion signatures with the additive impairment signature, the impairment originates in the structural portion of the plant or in a home without a CM.

Narrowband Interferer (NBI) Localization Process

- Gather pre-equalization data from node and determine different upstream path signatures.
- Use vector signal analyzer (VSA) to collect time recording of spectrum slice containing narrowband interferer.
    - Using VSA remove contributions that occurred at frequencies other than the spectrum slice containing the NBI.
- Using VSA, analyze fluctuations in time that NBI signal plus reflected version of it generated.
- Examine variation of amplitude to determine ripple and periodicity of ripple to determine delay and generate a delay/amplitude signature of impairment.
- Compare impairment distortion (i.e. delay/amplitude) signature with distortion signatures (i.e. delay/amplitude) of CMs.
- Source of NBI is located in portion of the plant between CMs that share signature and CMs that don't share signature.

(Localization process mirrors the one described in impulse localization example)