PROCEDURE FOR MEASUREMENTS AND STATISTICAL PROCESSING OF UPSTREAM CHANNEL NOISE IN HFC-NETWORKS

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ABSTRACT

A promising candidate for the growing bandwidth requirements of interactive multi-media services are hybrid fiber-coax CATV networks. They are however very susceptible to noise-funneling. We present a measurement method and statistical postprocessing for both ingress and impulse noise that is independent of the modulation and access technique used. The impact of ingress noise is evaluated for a TDMA/FDMA and CDMA access technique to illustrate this.

INTRODUCTION

Hybrid fiber-coax (HFC) CATV networks are excellent candidates to fulfill the growing demand to interactive television, telephony and data services. This is because of their high penetration level and bandwidth availabilty.
However, common European CATV-networks have a tree and branch structure that results in a phenomenon commonly called noise-funneling. This means that the communication, set up for a certain user of the HFC-network, is disturbed by the noise coming from all subscribers and all branches of the network. The noise characteristics have recently been studied in CATV-networks [1], [2], [3], [4], [5]. However, most measurements reported were based on maximum hold spectrum analyzer measurements, do not treat impulse noise or only take it into account when BER measurements are performed after selection of a certain modulation and access technique. We present a measurement procedure for upstream ingress and impulse noise characterization that is independent of the modulation and access technique used. Emphasis in this procedure is on the statistical processing of the measured data.

NOISE SOURCES

Noise funneling through an HFC-network can be subdivided into three categories; ingress noise, impulse noise and background noise. Ingress noise is narrowband noise caused by for instance short-wave broadcast and CB transmitters that couple radiatively to the HFC-network. Impulse noise is broadband noise that is caused by short term phenomena like lightning, switching of electrical equipment, car ignitions, etc.. Impulse noise can couple radiatively or conductively to the HFC-network

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and has a spectral content that decreases with increasing frequency. Background noise behaves nearly as white noise and is caused by the noise floor of all electrical equipment in (e.g., amplifiers) or attached to (e.g., TV-set) the HFC-network. In a well-tuned HFC-network background noise is negligible in comparison to ingress and impulse noise.

MEASUREMENT PROCEDURE

Ingress noise

A spectrum analyzer is used to measure every second an ingress spectrum. The measured spectra are transferred to a PC by means of a GPIB-interface. Every 15 minutes the recorded spectra are saved to a file. All these measurements are automatically performed and controlled by a measurement program written in LabView^{TM}. The stored data are processed using software also programmed in LabView^{TM}. To give a better understanding of the post-processed results we introduce the concept of an L-value. The ingress noise corresponding to an L-value of x% is the ingress noise level that is exceeded during x% of the time. One result of the post-processing is a 2 dimensional plot showing the ingress level corresponding to an arbitrarily chosen L-value as a function of time and frequency. The time step can be any arbitrarily chosen multiple of 15 minutes while the frequency step can be any arbitrarily chosen multiple of the resolution bandwidth of the spectrum analyzer. To that end the ingress is power integrated over the chosen frequency step and the ingress level corresponding to a certain L-value is calculated over the chosen time step period. We can then make any kind of cross-section of this 2 dimensional plot. As an example Figure 1 shows the ingress level integrated over 6 MHz for three different L-values calculated for each hour. We notice that the average ingress slightly increases during the evening hours while the ingress corresponding to a L-value of 0.1 % (peak values) shows a lot of fluctuations during the day.

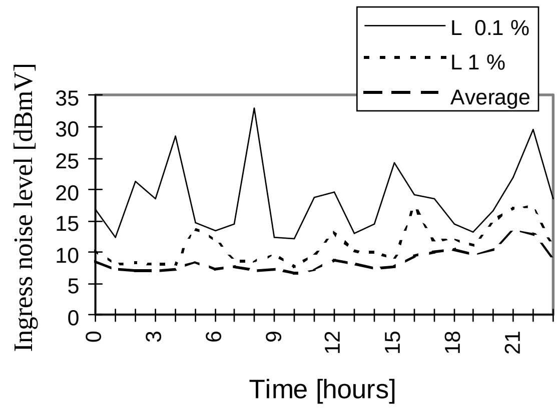

Figure 1: Ingress noise (17-23 MHz) as a function of time for three different L-values

Figure 2 shows the ingress noise as a function of frequency for three different L-values during the noisiest hour of the day (21 h). We see that the ingress level strongly depends on the used channel. From both figures we can also derive that the distribution function not only depends on the selected channel but also on the hour of the day. This means that a classic BER calculation based on a gaussian noise distribution is not appropriate. To illustrate the usefulness of the statistical processing of the ingress for a HFC operator we calculated the capacity variation due to ingress during the day for both a CDMA and a TDMA/FDMA access technique (see Figure 3).

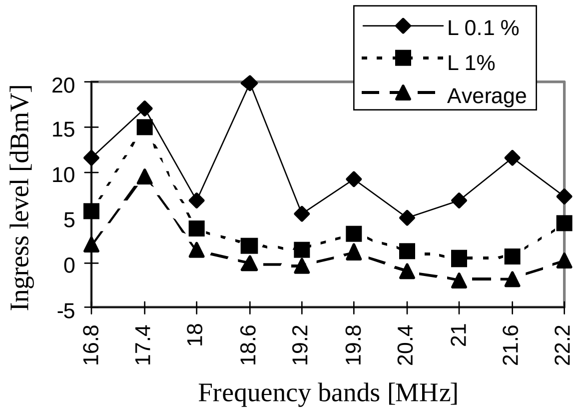

Figure 2: Ingress noise as a function of frequency (600 kHz channels) for three different L-values during the noisiest hour of the day (start frequencies of the bands are indicated).

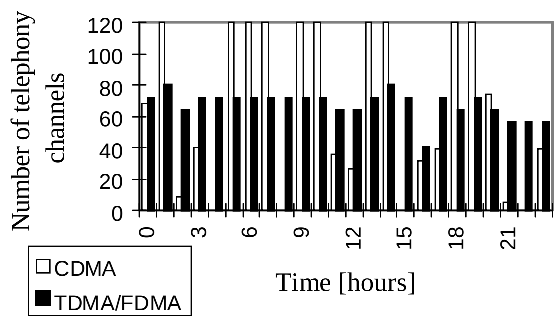

Figure 3: The number of telephony channels (64kbit/s) at a Bit Error Rate of at least 10^{-3} (CDMA : 17-23 MHz, TDMA/FDMA : 16.8-22.2MHz)

The calculations were based on the exact distribution functions derived from the ingress measurements. The CDMA system could fit 120 64 Kbps channels in 6 MHz and will reduce its number of PN codes to increases its noise robustness while the TDMA/FDMA system could fit 80 64 Kbps in 6 MHz (10 600 kHz channels each comprising 8 64 Kbps channels). The latter system will use frequency hopping to increase its noise robustness. A channel was accepted when it had a BER of maximum 10^{-3} which is acceptable since such a BER can be reduced to a BER of maximum 10^{-9} after forward error correction (FEC) and interleaving. Figure 3 shows that the capacity reduction of the CDMA system agrees well with the ingress fluctuation during the day (see Figure 1). At certain hours of the day the capacity drops to zero due to the presence of a big ingress peak at a certain frequency. For a TDMA/FDMA system such an event is not so dramatic since only one 600 kHz channel will be affected by such an ingress peak. In general we can state that FDMA will be favorable when a limited number of strong ingress peaks are present while CDMA will be more favorable when the ingress is more or less uniformly distributed over the used frequency band. We want to stress that no general conclusion can be drawn out of this comparison since the ingress was measured on a specific network.

Impulse noise

Impulse noise appears as spikes above the ingress signal level on an oscilloscope. The HP54520A oscilloscope in the sequential mode in combination with a PC with a GPIB interface is used to measure impulse noise automatically. The trigger level is set to a value (e.g. 3 dB) above the ingress level. For most of the access techniques the width and interarrival time of pulses surpassing a certain critical amplitude and in a certain frequency band are important. Because the impulses are measured from DC to the bandwidth of the oscilloscope, they are digitally filtered in the impulse noise processing program in bands that correspond to the band allocation scheme of an arbitrary access technique. The effect of impulse noise can be suppressed by using FEC and interleaving. To determine the suited parameters of these techniques for a certain HFC network we need to know the distribution of the interarrival time (IAT) of the impulses, filtered in a certain frequency band and with an amplitude surpassing the critical level for a certain modulation technique, for different classes of impulse widths. On Figure 4 we see that pulses with a small width occur more frequently than longer pulses. This distribution will allow us in the future to calculate the impact of impulse noise on the BER for a certain modulation technique.

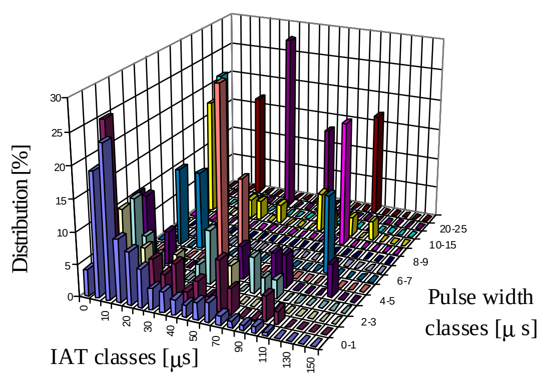

Figure 4: Distribution of the IAT of pulses filtered in the 17-23 MHz band for different pulse width classes

CONCLUSION

Due to the tree and branch structure of HFC-networks, ingress and impulse noise can severely degrade or even block the throughput on bi-directional HFC-networks. There is no doubt that much attention must be paid to the noise characterization. To that end a procedure is presented to measure and process statistically both ingress and impulse noise, that is independent of the modulation and access technique used. This makes the above described procedure an excellent tool for feasibility studies, for investigating which modulation and access technique shows the best robustness against noise or for monitoring purposes. To illustrate this the impact of ingress noise has been evaluated for a TDMA/FDMA and CDMA access technique.

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