Screening Attenuation – When enough is enough

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Introduction

This white paper describes the requirements to screening attenuation of cables and other components in the CATV coaxial networks. It is shown which screening attenuation that is required to prevent noise generated outside the network in degrading the distribution of DVB-C and DOCSIS 3.1 signals.

Conclusion

The upstream signals have the lowest power level at the entry to the amplifiers or nodes. So at this point in the network the CNR for a given noise level is smallest. And at this place the signal is flowing in a ground cable or a short jumper. These cables must have a screening attenuation above 95dB (class A+, EN50117-2-3) to effectively protect the DOCSIS 3.1 upstream signal down to 18MHz.

In the downstream the lowest power levels are at the subscriber outlet and in the cables connecting the outlet to the customer equipment. Therefore, any network components (e.g. outlets) or cables (modem cables, receiver leads etc.) at this point must be at least class A with regard to the screening attenuation for DVB-C signals, and class A+ for DOCSIS 3.1 signals.

The story behind the definition of Class A

Both for cables and other components used in coaxial CATV networks the class A screening attenuation has been defined to be 85dB (ref. EN60728-2, EN50117-2-3 and EN50117-2-4) for cables in the frequency range 30-1000MHz, and for components in the frequency range 5-300MHz, and then gradually decreasing to 80dB (300-470MHz) and 75dB (470-950MHz).

The screening attenuation is a measure for how well the CATV network is protected against the numerous sources of electromagnetic interferences from all sorts of sources.

The historical reason for the definition of the class A level 85dB is found in the notes to §5.4, Table 9 in EN60728-2.
Assumptions:
- The disturbing signal has a field strength of 106dBµV/m
- The device acts as a half-wave dipole, i.e. the coupling factor at 175MHz is 11.2dB

- The screening attenuation is class A, i.e. 85dB
- The analogue TV signal has an average power level of 70dBµV

The result is that the picked-up disturbance has the power level
$$106dBµV - 11.2dB - 85dB = 10dBµV$$
So the ratio between the TV signal and the disturbance is 60dB, which is perceived to be the minimum ratio for a high quality analogue TV signal.

The coupling factor decreases by the inverse of the signal frequency, which explains why the class A requirement decreases as the frequency increases; the requirements ensures that the picked-up disturbing signal remains below 10dBµV up to 950MHz.

How noise is entering the CATV network

As it can be seen from the above explanation, there are many assumptions linked to the definition of class A screening attenuation. First and foremost the standards are from the days of analogue TV; nowadays signals are DVB-T, DOCSIS 3.0, and DOCSIS 3.1. So are the class A requirements still the right ones?
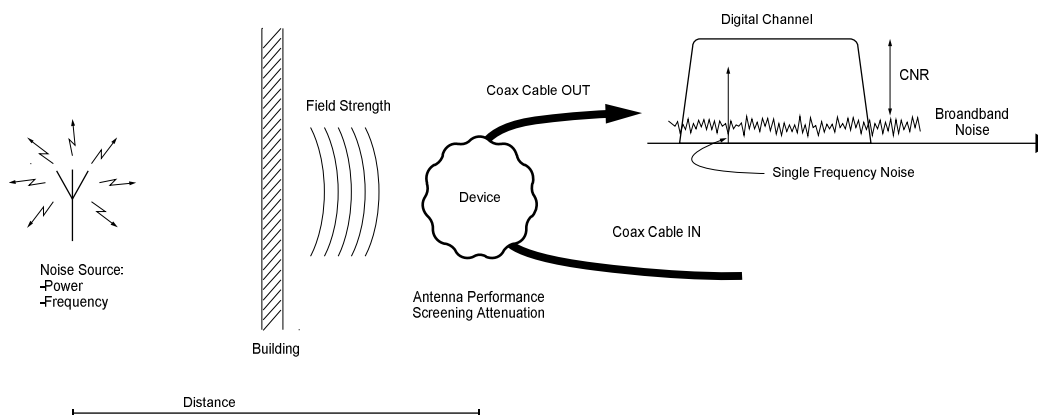

Figure 1 The path from a noise source to a picked-up signal in a device in a CATV network. The noise source generates an electromagnetic field with a certain field strength at the location of the device. The antenna performance of the device, described as a coupling factor, describes how much of the electromagnetic field that is picked up on the outside of the device, and then the screening attenuation is a measure of how much of this picked up signal that penetrates into the inner circuit.

First of all, a look at the physics behind the correlation between noise sources and picked-up noise. As shown in Figure 1 the noise is generated by some sort of an antenna, transmitted through the air (and some construction material), before being picked up on the outside of a device (cable or other component) in the CATV network. Due to the non-perfect screening attenuation the noise results in a disturbance to the signals transmitted inside the CATV network. The magnitude of this disturbing signal in thus a function of:
- The power level of the disturbing source including the radiation characteristic of this source. The contribution is proportional to the square root of the power.

- The distance between the noise source and the device. The contribution is proportional to the inverse of the distance.
- The material of any building or construction enclosing the device. The attenuation of materials varies from a few dB for e.g. glass to 10-20 dB for thick walls made in concrete.
- The coupling factor, which is a measure of how well the device acts as an antenna. It is the ratio between the field strength generated by the noise source and the picked-up signal at the outer part of the device, e.g. the disturbance signal generated in the outer conductor of the coaxial cable. So the coupling factor is the general antenna performance of the device. As in the above example it is assumed that the device acts as a half-wave dipole. This might be true for cables since these almost always are several meters long, but for components like outlets and other passives the antenna performance might be far lower, perhaps 10-20dB. The coupling factor is proportional to the inverse of the frequency of the disturbing signal.
- The screening attenuation of the device which is a measure of how much of the disturbing signal picked-up on the outside that is transferred to the inner conductor of the device, i.e. the part carrying the CATV signals. The screening attenuation is depending on how the outer screening of the coaxial cable is constructed; how many wires in the braiding, how many layers of foils, etc. Also, the screening attenuation depends on the workmanship, both in the assembly of the components during production, and how well connections are made in the field during installation. Anyhow, a rule of thumb is that better screening means higher device cost, so a trade-off has to be taken.

When one needs to draw a conclusion on how much screening attenuation is needed, there are quite many uncertainties. Obviously, a CATV network situated close to a noise source increases the need for screening. So which field to use in the worst case calculations?

As in EN60728-2 the field strength is set to 106dBµV/m, though 120dBµV/m is also used in some of the graphs below. A CATV network installed underground or inside buildings has inherently an extra level of protection from the soil or from building construction. In worst case calculations it is assumed that there is only free air from the noise source to the device.

The most open question is how well is the device – being it a cable or a network component – acting as an antenna? A coax cable several meters long might be a good antenna, if it is orientated properly to the noise field, and might not pick up any noise if the orientation is different. The dimensions of most other components in CATV network are in most cases shorter than the wavelength of the noise, and the coupling factor can be

low. So using the assumption that any device acts as a half-wave dipole antenna is in general really a worst worst-case.

Field strength

Assuming that the noise source with a power *P* (in W) acts as an half-wave dipole antenna then the field strength *E* of the electro-magnetic field in the distance *D* (in meters) from the source can be calculated by the formula:

$$E \ [dB\mu V/m] = 20 \times \log\left(7.02 \frac{\sqrt{P \ [W]}}{D \ [m]}\right) \qquad [1]$$

Some relevant examples are summarized in table below.

Source	P	D	E
Mobile Phone	12.6 mW	4 m	106 dBµV/m
LTE Base Station	20 W	31 m	120 dBµV/m
LTE Base Station	20 W	157 m	106 dBµV/m
FM Broadcast	30 kW	1200 m	120 dBµV/m
DVB-T Broadcast	50 kW	1500 m	120 dBµV/m
DVB-T Broadcast	50 kW	7900 m	106 dBµV/m

Single frequency noise

When comparing the picked-up noise with the digital signals like DVB-C, DOCSIS 3.0, and DOCSIS 3.1, one can distinguish between single frequency noise and broadband noise. The digital signals are generally very robust towards single frequency noise, as shown in the example in Figure 1. For DVB-C the peak noise might exceed the power level of the QAM-block and still the TV reception is functioning. For DOCSIS 3.1 it is possible to switch of a single or a few subcarriers if there are any narrow band disturbances. The result of switching off 10 subcarriers out of the 7600 in an OFDM block is a bit rate reduction of only 0.13%.

Broadband noise

More critical is the noise covering several MHz in bandwidth. This has to be handle as described in EN60728-1 § 4.11.4. The main sources of broadband noise are the terrestrial DVB-T broadcast, FM broadcast, and LTE.

When using a spectrum analyzer to measure the digital signal, the relation between the maximum recorded power *S* and the total power in digital signal, e.g. the DVB-C QAM256 block $S_{D,RF}$ is:

$$S_{D,RF} = S + 10 \log \frac{BW}{RSBW} + K_{SA} \qquad [2]$$

BW is the bandwidth of the digital block, i.e. 6.95MHz
RSBW is the resolution bandwidth of the spectrum analyzer, e.g. 300kHz.
K_{SA} is a correction factor with the value 1.7dB (En60728-1, Annex I).

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For the broadcasted DVB-C signals the minimum power $S_{D,RF}$ at the subscriber outlet is specified in EN60728-1 §5.4 Table 4 to be 54dBµV, so with the RSBW = 300kHz, S is then 38.7dBµV.

The noise level N in this block is measured in the same way as S with the DVB-C signal switched off. The signal-to-noise ratio is then given by:

$$S_{D,RF}/N = S - N$$

For DVB-C the minimum value for the $S_{D,RF}/N$ is 32dB, so the noise floor must be below 6.7dBµV.

A plot of the required screening attenuation in order to achieve a noise floor of 6.7dBµV with either field strength of 106dBµV/m or 120dBµV/m for a half-wave dipole antenna is shown in Figure 2.
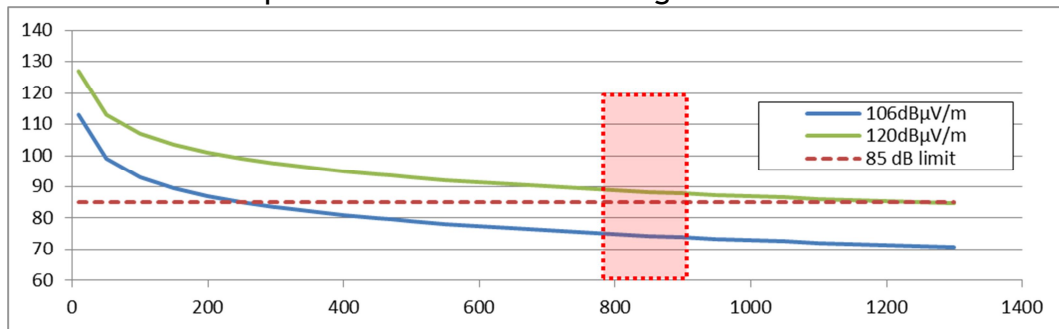

Figure 2 The required screening attenuation to achieve a noise level at 6.7dBµV in a field of either 106dBµV/m or 120dBµV/m assuming a coupling factor like a half-wave dipole antenna. The red area indicates the frequency range of the LTE.

As shown in Figure 2, a screening attenuation of 85dB is sufficient to protect effectively the DVB-C signals from LTE noise or any other broadband noise above 250MHz with the field strength 106dBµV.

The requirements to the downstream DOCSIS 3.1 are stated in the DOCSIS 3.1 standard. For a QAM4096 signal, the minimum CNR is 41dB (below 1GHz), and the minimum channel power is 54dBµV, measured in a channel 6MHz wide. Using formula [2] this gives a signal level S = 39.3 dBµV (RSBW = 300kHz, BW = 6MHz since OFDM channel consists of a continuum of 6MHz channels), and a noise level N = -1.7dBµV. The consequence of such a low noise level to the necessary screening attenuation is shown in Figure 3.

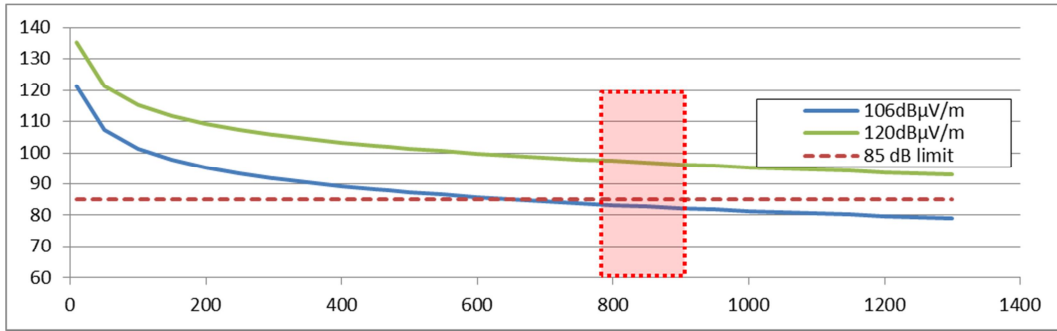Figure 3 The required screening attenuation to achieve a noise level at -1.7dBµV in a field of either 106dBµV/m or 120dBµV/m assuming a coupling factor like a half-wave dipole antenna. The red area indicates the frequency range of the LTE.

As the maximum noise floor for the DOCSIS 3.1 signal is lower than for the DVB-C signals the class A screening attenuation 85dB, is only sufficient from about 650MHz and up to protect the DOCSIS 3.1 from broadband noise.

Because the DVB-C signals have the lowest required CNR, and thus are more robust to broadband noise, it is recommended that in the channel plan the DVB-C channels are placed in the low frequency range, and then only place DOCSIS 3.1 signals above 650MHz, keeping in mind that DVB-C channels anyhow have to be placed below 862MHz.

Looking at the upstream DOCSIS 3.1 signals, the standard states the required CNR for a QAM1024 is 35.5dB. The minimum signal power depends on the nodes and amplifiers used in the network, and some operators have chosen the value 70dBµV, in a 6MHz channel. Making the same calculations as for the DOCSIS 3.1 downstream gives the signal level S = 55.3dBµV, and the noise level N = 19.8dBµV. This is used to make a plot for the upstream frequency range, see Figure 4.

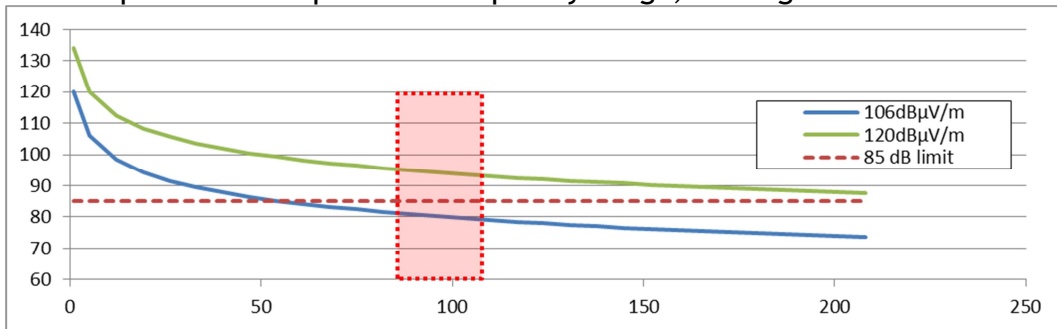Figure 4 The required screening attenuation to achieve a noise level at 19.8dBµV in a field of either 106dBµV/m or 120dBµV/m assuming a coupling factor like a half-wave dipole antenna. The red area indicates the frequency range of the FM broadcast.

The class A screening attenuation is only sufficient to protect the upstream DOCSIS 3.1 signals at frequencies above 55MHz. Using class A+ (minimum 95dB) moves this lower frequency limit to only 18MHz.

Conclusion - Repeated

The upstream signals have the lowest power level at the entry to the amplifiers or nodes. So at this point in the network the CNR for a given noise level is smallest. And at this place the signal is flowing in a ground cable or a short jumper. As Figure 4 shows these cables must have a screening attenuation above 95dB (class A+, EN50117-2-3) to effectively protect the DOCSIS 3.1 upstream signal down to 18MHz.

In the downstream the lowest power levels are at the subscriber outlet and in the cables connecting the outlet to the customer equipment. Therefore, any network components (e.g. outlets) or cables (modem cables, receiver leads etc.) at this point must be at least class A with regard to the screening attenuation for DVB-C signals, and class A+ for DOCSIS 3.1 signals.

Type	Recommended screening attenuation
IEC Cables for TV/FM	Class A
FF Cables for Modem	Class A+
Outlet	Class A+

Table 1 Recommended screening attenuation classes for cables and components.

The above conclusion is drawn on the assumption that the worst-case noise signal has a field strength of 106dBµV/m. In the close proximity to broadband sources as terrestrial TV transmitters and LTE base station higher filed strength exists, thus higher screening attenuation might be needed depending of antenna performance of the device.