Bandwidth

Bandwidth is the range of frequencies the device is intended to work by. Frequency range for radio and television signals is 47-862 MHz.

Signal-to-Noise ratio (C/N)

Signal-to-Noise ratio C/N shows how many times the power of a signal (or a carrier) is greater than the power of noise. It is usually expressed in decibels:

$$C/N = 10 \cdot \log\left(\frac{P_{signal}}{P_{noise}}\right) \text{ [dB]}$$

Signal-to-Noise ratio *45 dB* provides very high picture quality, *25 dB* causes large amount of distortions in the picture and therefore lower quality. Usually *42 dB* is required in CATV coaxial cables.

Gain

The gain G is defined as the ratio of the power delivered to the output to the power available from the input. The greater the gain, the more the signal is amplified in the amplifier. Gain is usually expressed in decibels (*dB*):

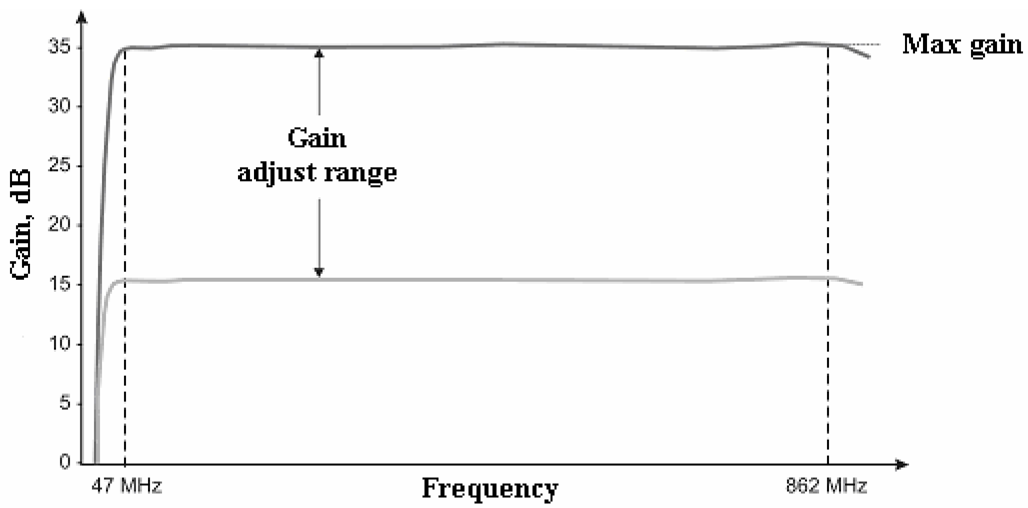
$$Gain = 10 \cdot \log\left(\frac{output\_power}{input\_power}\right) \text{ [dB].}$$

CATV amplifier gain is typically 25-40 dB.
Antenna amplifier gain is typically 10-30 dB.

Gain adjust range

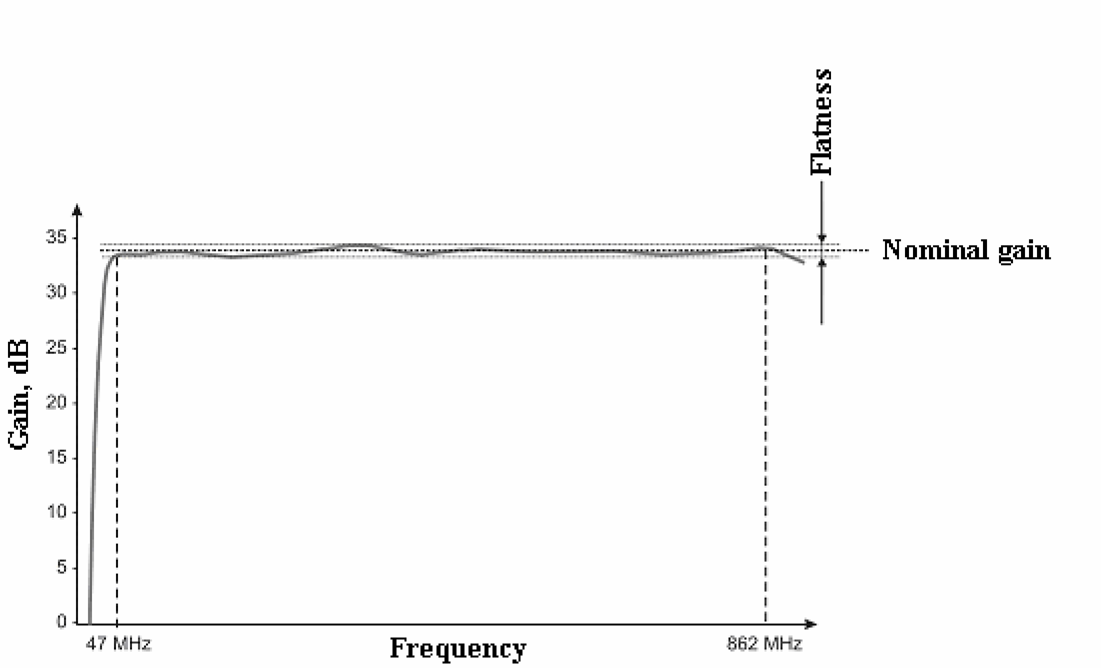
The range of adjustable gain shows the limits of adjusting the gain

For example, in case the maximum gain of an amplifier is 35 dB and the range of adjustable gain is 20 dB, the gain of the amplifier could be adjusted in the range of 15-35 dB.



Flatness

In an ideal amplifier all frequencies are amplified equally. This means that the graph of an ideal gain depending upon frequency is absolutely flat. This is never achieved in real amplifiers and there is always some difference from the overall flatness that is expressed in decibels.



The flatness of amplifiers is typically ±*1…2 dB,* in high quality amplifiers ±*0.5…0.6 dB.*

Thermal noise

Due to molecular movement of a substance of which the electronic components are made of, there always exists so-called thermal noise at room temperature. In 75-Ohm CATV systems the level of noise floor is approximately 1 microvolt. All signals below 1 microvolt cannot be recovered. Signal levels are usually expressed in dBmV (decibel-millivolts) – 1 microvolt is the same as –59 dBmV (called *noise floor*) and therefore it is not allowable to decrease signal level below –59 dBmV. Thermal noise is also amplified in an amplifier, in addition to a signal, and therefore in the amplifier output the noise level is greater than the noise floor.

Noise Figure

Every amplifier amplifies both the signal and the noise delivered to the input. Since an amplifier is never ideal, it also adds some self-noise during the amplifying process and therefore in the amplifier output there is a sum of amplified input noise and amplifier self-noise in addition to the amplified signal. Thus, the signal-to-noise ration always decreases between amplifier input and output. This decrease is expressed by noise figure *(NF*) and is calculated in decibels:

$$NF = 10 \cdot \log\left(\frac{Signal - to - noise \quad ratio \quad at \quad input}{Signal - to - noise \quad ratio \quad at \quad output}\right) \text{[dB]}.$$

The lower the noise figure, the lower the amplifier self-noise is. Noise figure is different for different frequencies, therefore for wideband devices (CATV amplifiers) many NF values are often given. Typically NF = *4…9 dB,* in low noise amplifiers (*LNA*) NF = *0.5…2 dB.*

Cascading amplifiers

Noise figure of cascaded amplifiers is expressed by the formula:

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \ldots$$

in which F_n is the amplifier noise figure, G_n is the amplifier gain and n is the amplifier order number in a cascaded circuit. It could be seen that the first amplifier (F_1) has the greatest effect for overall noise figure F. Thus, it is very important to use an amplifier with low noise figure at the beginning of a cascaded circuit. It is also significant to keep a cable between an antenna and the first amplifier as short and lossless as possible.

Maximum output level

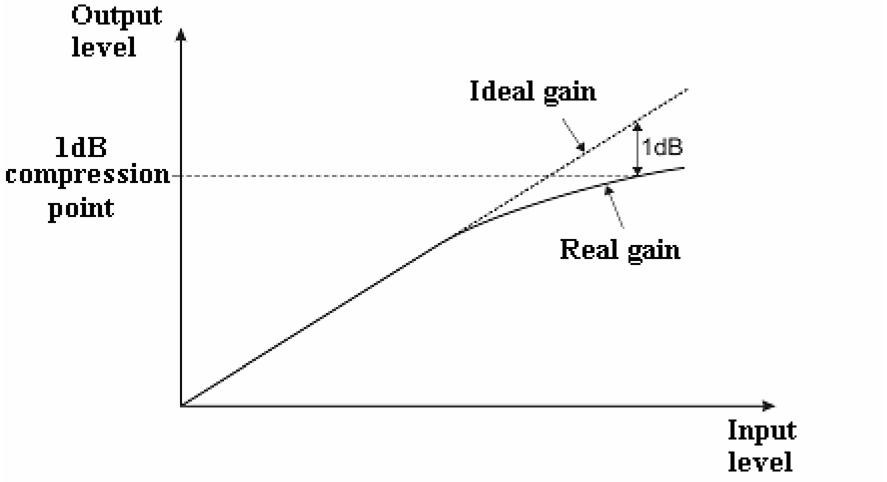
Every amplifier has a limit of maximum output signal level. Increasing the input signal level, the output signal level also increases until maximum output level is achieved, one that cannot be exceeded.

If the input signal level is too high and output signal is at maximum output level, then the shape of the signal, called the waveform, is not amplified correctly. This causes signal distortion and lowers the quality of CATV picture.

It is therefore required to keep input signal level in an allowed range. The task is simple if there is only one signal in input, but in CATV systems voice, picture and colors are delivered simultaneously in many channels. The sum of all signals must be kept low enough to prevent amplifier from exceeding maximum output level.

1 dB compression point

An ideal amplifier amplifies every signal equally. This is well achievable in the available amplifiers if the input signal is small. In case the power of an input signal increases, amplifier gain is not constant anymore and starts dropping. Output level at which the amplifier gain has dropped 1 dB below its small signal value, is called *1 dB compression point*.



Parameters that describe nonlinear distortions are always given for small signal conditions, i.e. below 1 dB compression point. All CATV devices are intended to work below 1 dB compression point.

Distortions and types of amplifiers

Every device the signal passes through may distort the signal. There are two types of distortions – linear and nonlinear – and both of them exist in amplifiers. Linear distortions are caused by linear circuits (consisting of resistors, capacitors, inductors) where some frequencies are amplified more than others (amplifier flatness). Nonlinear distortions are caused by nonlinear circuits (transistors, diodes, varistors etc.) wherein such harmonics and combination frequencies may occur that they interfere with neighboring channels and decrease the quality of CATV picture. It is therefore recommended to use an amplifier that keeps the second and third order nonlinear distortions minimal. Higher order distortions are usually not analyzed, since their influence is minute.

One of the possible solutions is to use *push-pull* amplifiers, in which the positive and the negative side of the sine wave in the input are amplified separately. Thus the second order distortions are significantly decreased.

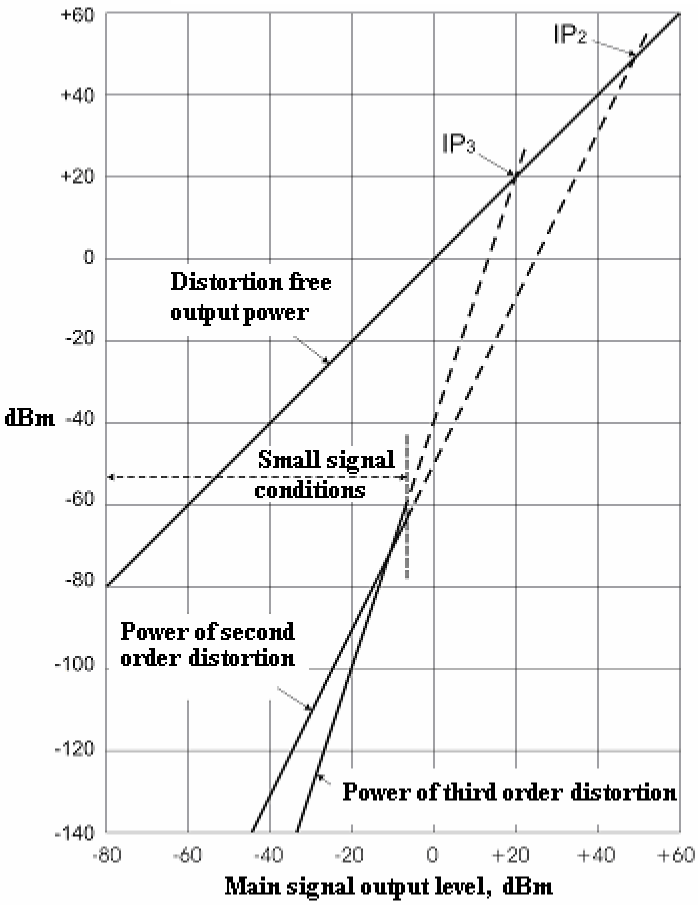
Another possibility is to use *feed-forward* amplifiers wherein the amplified signal is subtracted from the input signal and the remainder signal expresses the amplifier distortions. The remainder signal is also amplified and subtracted from the amplifier output signal. After such processing, the output signal is practically distortion free.

Measuring distortions

The amount of distortions is defined by *Intercept Point* (*IP*), usually by IP_2 and IP_3. IP_2 expresses the level of second-order distortions and IP_3 the level of third-order distortions.

Both parameters are measured by two test tones at frequencies F1 and F2. In nonlinear circuits the spectral components at frequencies $\pm m*F1 \pm n*F2$ will occur, where *m* and *n* are positive numbers. The order of the distortions is defined as a sum $m+n$. Thus, components with frequencies *2*F1-F2, 2*F2-F1, 3*F1* and *3*F2* are all products of third order distortions. *2*F1-F2, 2*F2-F1* are two tone third order distortion products, because they depend upon two tones – *F1* and *F2*. *3*F1* and *3*F2* are one tone third order products, because they depend upon one tone. For example, in case the test tones are 100 MHz and 101 MHz, two tone third order products are 99 and 102 MHz and one tone third order products 300 and 303 MHz. It may be seen that two tone products lie very close to the test tones and they are very difficult to filter out (often impossible).

When increasing the gain, the second order distortions increase two times faster and the third order distortions increase three times faster than the input signal. In case the input signal is low, distortion products are also very low and do not disturb signal. When input signal increases, the distortion products also start increasing, doing it 2 or 3 times faster and thus beginning to significantly disturb the signal at a high signal level. Theoretical point at which the signal level and the level of distortions are equal is called IP_2 or IP_3 point.



An amplifier is always intended to work at much lower frequencies than IP_2 or IP_3. Those parameters are still widely used to describe amplifiers, since the values of IP_2 or IP_3 may be well used to estimate the distortion level also in small signal conditions. The greater the IP_2 and IP_3, the lower the distortion products and the higher the quality of CATV signal.

There are some special parameters to describe CATV system amplifiers. One of them is called *intermodulation distortion* (standard DIN 45004B), in which 3 test tones are used simultaneously and the voltage of a combination frequency occurring in the neighboring channel is measured – the lower the measured voltage, the lower the distortion.

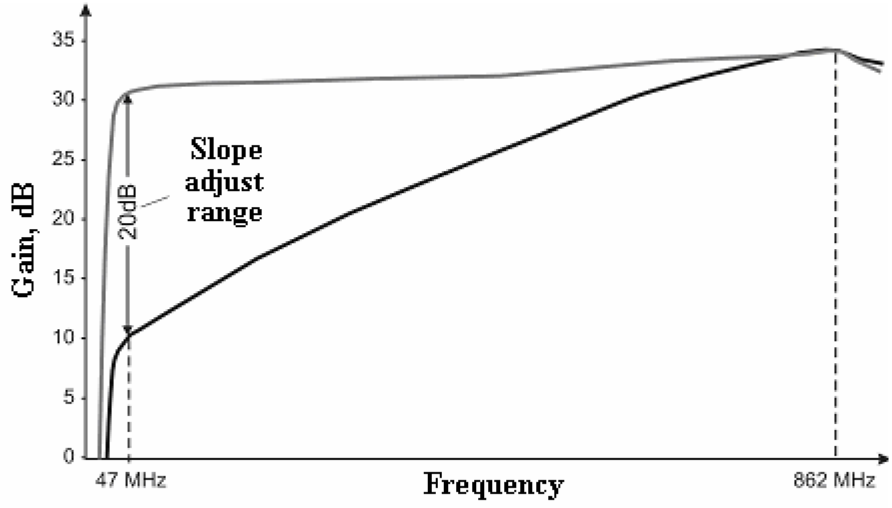
Parameters *CTB* (*ratio of carrier to composite third order beat*) and *CSO* (*composite second order distortion*) are also often used to give the key features of a CATV amplifier. Test tones are applied to all channels simultaneously, except one in which only the distortion product occurs. The level of a distortion product gives information about the overall distortion of an amplifier.

Parameters that describe an amplifier predict the amplifier distortional behavior only below 1 dB compression point.

Slope correction, slope adjust

Usually a coaxial cable is used to deliver CATV signal. In a coaxial cable the signal losses are greater at higher frequencies and smaller at lower frequencies. To provide a homogeneous signal, an amplifier should amplify lower frequencies less than the higher ones. It is called a slope correction.

How much the gain for lower frequencies should be lower than the gain of higher frequencies depends on cable structure and length. Therefore it would be useful to adjust the slope for the given conditions. This is called slope adjust and it is expressed in decibels at the lowest frequency of a CATV system (*47 MHz*) (see diagram).



Rantelon amplifiers, those that possess the slope-adjust feature, are typically adjustable in the range of 20 dB.

Power supply
There are two parameters that describe the power of a device – nominal voltage and current use.

Nominal voltage is the required and the only allowed voltage the device may be supplied with. Home devices usually use the voltage of *220 V*. If the nominal voltage of a device is lower (e.g. *16…17 V* for Rantelon amplifiers), a proper power adapter needs to be used.

Current use shows which current the device uses for work. It is expressed in milliamperes (*mA*). In case a power adapter is used with the device, it must be guaranteed that the maximum allowed current of the adapter is not lower than the current use of the device.

In order to calculate the energy in kilowatt-hour, one can use the following formula:

*energy [Wh] = current in amperes * voltage * hours*

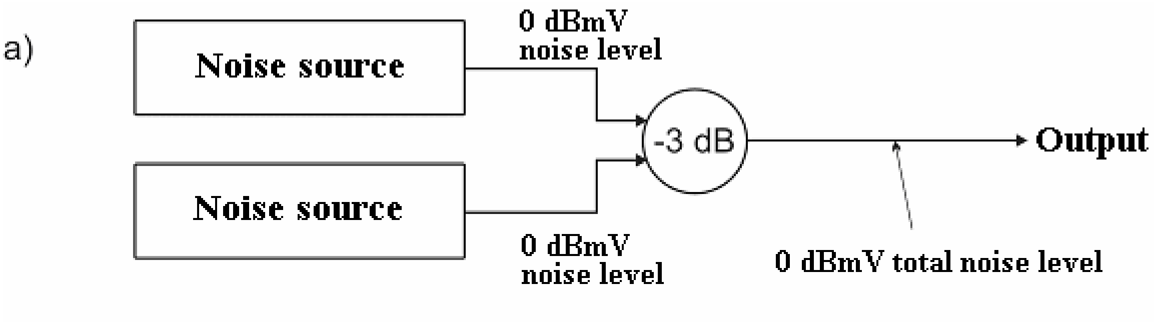
For example, if the current is *100 mA* (*= 0,1 A*) and voltage *17 V*, the device uses *0,1*17*24*365 = 14,9 kWh* energy per year. When calculating energy use, one needs to take into account the energy use of the power adapter, which is different for different adapters – the lower the energy use, the more economical the device.

Test point
Test point is an additional output port to test the device. It is a very useful feature for situations wherein the device is already mounted and working and it thus be inconvenient to disconnect the cables again.

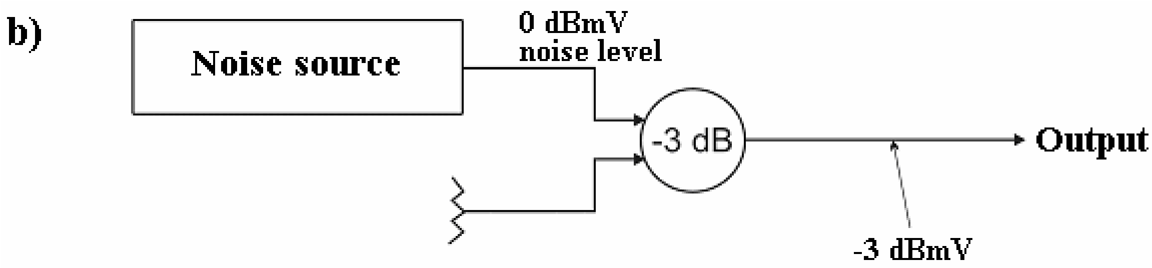
The output power of amplifiers is usually very high. In order to protect the measuring apparatus from breakdown the power is strongly decreased in a test point. The amount of signal decrease is expressed in decibels.

In Rantelon amplifiers the signal in a test point is typically 20-30 dB lower than the output signal.

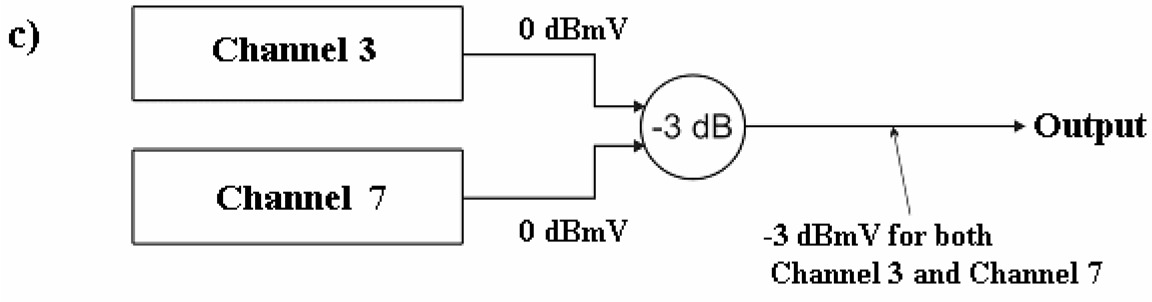
Using devider as a combiner
Next examples explain how to connect a splitter as a combiner.



In diagram *a* there are two noise sources feeding a simple CATV splitter connected as a combiner. Assuming the splitter loss is 3 dB per port (half of the power), the noise entering the two ports at 0 dBmV will be attenuated at -3 dB, but will power-combine + 3 dB, causing the signal level in output to become 0 dBmV. Thus, the output noise power equals the input noise power.

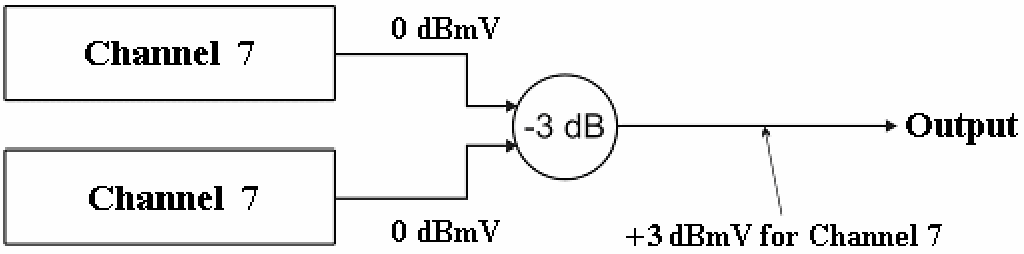


In diagram *b* one of the noise sources is disconnected. Half of the noise power will heat the resistor inside a splitter and another half reaches the splitter output, causing the signal level in output to become -3 dBmV. Therefore the output noise power is 3 dB less than input noise power.



In diagram *c* there are two signal sources feeding the two ports of a splitter (functioning as a combiner) and each generator is operating on a different television frequency. As the signals are different, a half of the power of both signals is lost in splitter resistor and therefore the power of both signals in the splitter's output is -3 dB lower compared to the input.

d)



In diagram *d* there are two signal sources feeding the two ports of the splitter (functioning as a combiner) and both sources are tuned to the same frequency and phase. As the signals are identical, the voltage on the resistor inside the splitter is 0 and therefore the power loss is also 0. Thus, signal power in the splitter's output is 3 dB greater (2 times greater) compared to the input power.

In case two antennas are used to receive a signal and cable lengths between antennas and splitter are equal, 3 dB greater signal would be achieved in comparison to the receptive capacity of one antenna only.