KWS ELECTRONIC TEST EQUIPMENT GMBH

APPLICATION NOTE

AN 005

Spectrum Analysis

KWS GERMAN ENGINEERING

Contents

Chapter 1

About this document

This document contains information about the spectrum analysis with measuring receivers from KWS-Electronic GmbH (e.g. AMA 310, Varos 107, Varos 109, Varos 306)

1.1 Revisions

V00.01 July 2014
Initial publication

1.2 Reference documents

This application note refers to the following documents:

- Operating instructions for KWS measuring receivers

1.3 Contact to manufacturer

For the latest information about KWS-Electronic products please visit our web site: **www.kws-electronic.de**. Here you will find the necessary contact data.

1.4 Terms and abbreviations

The following abbreviations are used in this document:

BW	Bandwidth
CC	Colour carrier
I	Ingress
IC	Image carrier
IF	Intermediate Frequency
kHz	Kilohertz ($1*10^3$ Hz)
Max-Hold	Recording the max. level following several measurements
MER	Modulation Error Ratio
MHz	Mega-Hertz ($1*10^6$ Hz)
OFDM	Orthogonal Frequency Division Multiplexing
Pixel	Picture element
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RBW	Resolution Bandwidth
RF	Radio Frequency
S/N	Signal-To-Noise Ratio
S/(N+I)	Signal-To-Noise-And-Ingress Ratio
SC	Sound carrier
SPAN	The range between the start and stop frequencies
TILT	Tilt / slope

Chapter 2

Spectrum analysis using KWS-Electronic measuring receivers

2.1 Introduction

The facts presented in this document are generally valid. They should enable the user of KWS test receivers to optimally deploy the spectrum analyser and to correctly interpret the displayed values. Device-specific issues such as operation or technical data are not addressed. For these, please refer to the manufacturer's respective operating instructions - see www.kws-electronic.de.

All screenshots were taken with the measuring receiver AMA310. Owing to the generality of this document the knowledge gained can be applied to in any other KWS test receiver.

2.2 Basics

A spectrum analyser basically shows the frequencies contained in a signal as well as the energy, signal strength, or voltage level the frequencies possess.

While an oscilloscope analyses a signal in so-called time domain (amplitude variation as a function of time) you can evaluate a signal in the frequency domain (amplitude vs. frequency) using a spectrum analyser. The time domain analysis contains the same data as the frequency domain analysis. By means of mathematical operations both types of analysis can even be converted to the other. You normally decide on whether to use an oscilloscope or a spectrum analyser depending on application and fault type. In the case of TV and radio signals the method of choice is almost always the spectral representation method.

In a signal that is measured with a measuring receiver there are always frequency components that are relevant for data effective (TV, Internet) and are used (useful signal) as well as frequencies and signal parts that interfere with the useful signal.

Interference signals can more or less be evenly distributed over the complete frequency range (noise, level normally lower) or may occur at discrete frequencies (discrete interferences, level can be relatively high). We will not go, at this point, into the causes of the noises (e.g. shot noises, thermal noises, etc.) and discrete interferences (e. g. ingress).

2.2.1 SPAN

The span is the frequency range shown in the display of the spectrum analyser. If the analyser function is activated on a KWS measurement device the spectrum is shown in the full span. That means that the analyser displays the complete frequency range currently set on the measuring device (e.g. 910 MHz to 2150 MHz for satellite reception or 5 to 65 MHz for the return channel range).

In order to evaluate a smaller frequency range with a higher resolution the span can be reduced for each measurement range in several steps.

2.2.2 RBW

The RBW (Resolution Bandwidth) is the bandwidth with which a frequency is measured.

That means (example values): If the measurement device is tuned to a frequency of 500 MHz and the RBW is 500 kHz then the measurement device will consider all signal energy (or voltage swing) between 499.75 MHz and 500.25 MHz. The measurement returns **one** voltage value. For the sake of completeness, it is mentioned at this point that there is a peak and an average detector available for the measurement. However, the operation of the two measurement types is not relevant for the interpretation of the spectra.

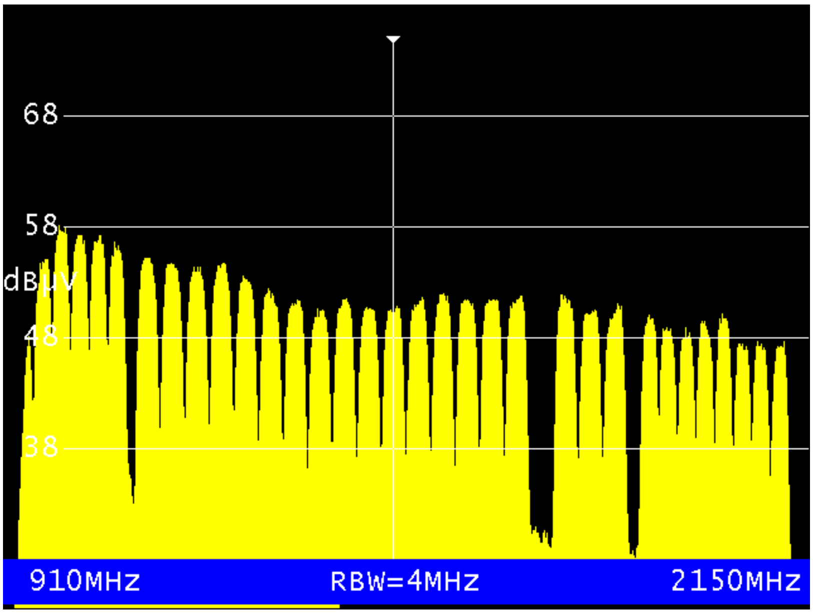
2.2.3 Sweep and sweep time

The term sweep is used if the frequency band that is to be measured is divided into individual sub-bands and each sub-band is measured separately and successively.

The duration of the measurement of the whole frequency band is known as the sweep time

2.2.4 Example

The following figure illustrates the aforementioned terms using an example of the spectrum sweep of a SAT IF signal from the ASTRA satellite.



The SPAN here is 1240 MHz (2150 MHz – 910 MHz; SAT-Full-Span); the RBW is 4 MHz. The RBW is permanently coupled with the SPAN, in other words the device automatically selects the RBW depending on the SPAN used. Which RBWs are available for the different measurement ranges is dependent on the device and measuring range – please refer to the respective user manual.

So as to create the spectrum as shown above the measurement device divides the span into part bands. The following approach plays the main role when determining the frequency steps between two measurements.

For example, the display of the AMA 310 has a resolution of 640 (horizontal) x 480 (vertical) pixels. As a result, a frequency step between two measurements of less than 1240 MHz / 600 ≈ 2 MHz makes no sense because each vertical display line cannot represent more than one level value.

The SAT spectrum is measured with a frequency separation of 2 MHz. The signal power is determined within a 4 MHz bandwidth (RBW) for each measurement frequency and shown on the display. The current measured frequency is displayed on the yellow progress bar at the bottom of the screen.

If a sweep is completed (i.e. the highest frequency is reached – in this case 2150 MHz) a new sweep begins at the lower band limit. The sweeps continue indefinitely until the user leaves the analyser or the continuous measurement is manually stopped.

The cursor can be moved in the spectrum using the measurement device’s arrow keys. The measurement device shows – depending on type, either in the spectrum view or in the LCD measurement display – the current frequency of the cursor and the measured level at this position.

Attention! ⚠ The level value refers exclusively to the level within the RBW at the current position of the cursor.

2.2.5 Max Hold Function

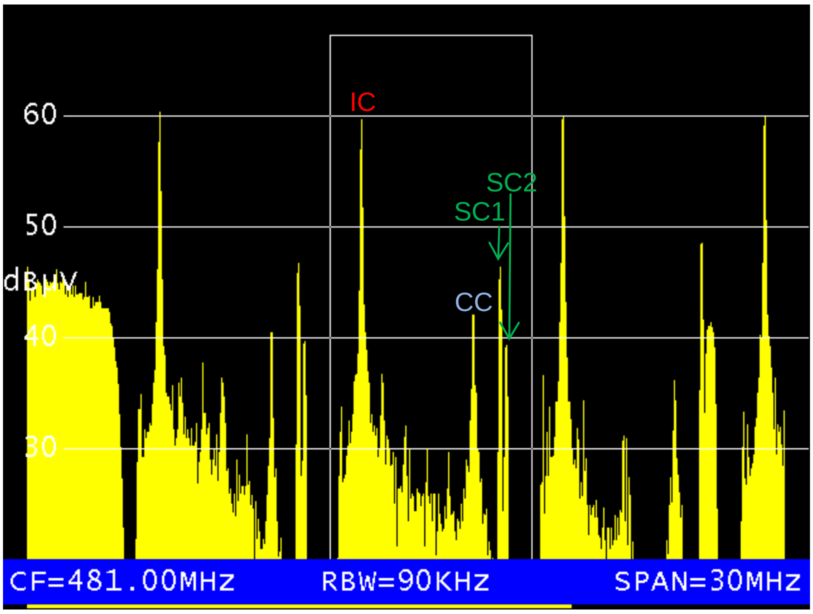
The Max Hold function can be activated and deactivated in all analyser ranges. When the spectrum analyser is at the normal setting the previously measured level at a specific frequency is overwritten with every new sweep. When the Max Hold function is activated the new value is only entered in the spectrum if it exceeds the corresponding value of the previous sweep. This function can be very useful for example for ingress measurement (see below).

2.3 Level measurement with the spectrum analyser

2.3.1 Radio signal spectra

The most important difference to observe when analysing the spectrum for antenna measurement receivers is between analogue and digital TV signals. Since the introduction of DVB-T and the analogue switch-off for ASTRA satellites the analogue TV signals (PAL) only occur in the cable networks. Without going into the technical details here of analogue and digital modulations (QPSK / 8-PSK for SAT, QAM for DVB-C and DOCSIS, OFDM for DVB-T / -T2) there is a simple difference that can be pointed out.

Discrete carriers within the channel bandwidth can be observed in the spectrum for analogue PAL signals. A TV channel in the cable TV spectrum is highlighted in the following picture. You can recognise the image carrier (IC), the colour carrier (CC), and the two sound carriers (SC1 and SC2). There are various standards that stipulate which frequency and level offsets the sub-carriers have to have with regards to the image carrier.



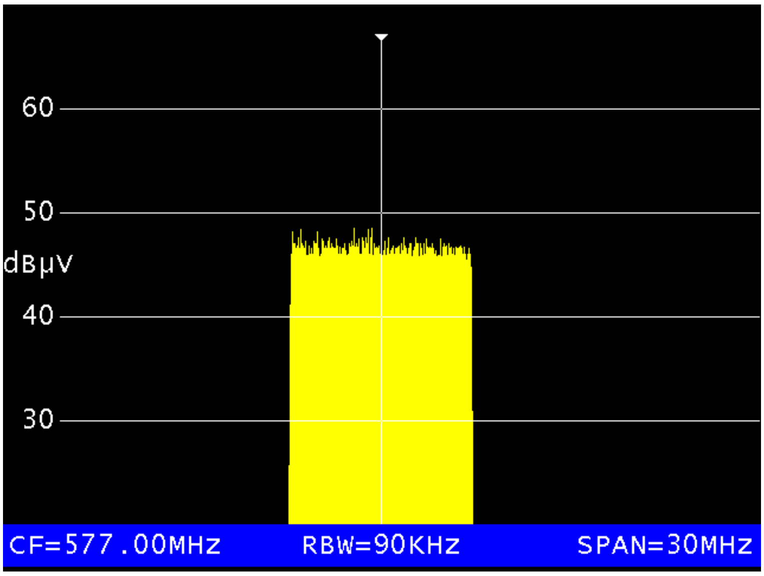
The peak value of the image carrier is measured per definition when measuring the level of an analogue TV channel. The KWS measurement devices use a measurement bandwidth of 200 KHz. Here the maximum must be determined within the period of a half image (peak detector).

In contrast to this, the signal power for all digital modulations is distributed evenly within the channel bandwidth. Yes, the signals differ according to standards (DVB-S/S2, DVB-C/C2, DVB-T/T2, Euro-/UsDOCSIS, DAB, etc.); differ according to roll-off factor and symbol rates with regards bandwidth and spectrum fall at the band and channel limits respectively. Irrespective of this, the spectrum of a digital channel is easy to distinguish from an analogue channel as is clearly shown in the following illustrations.

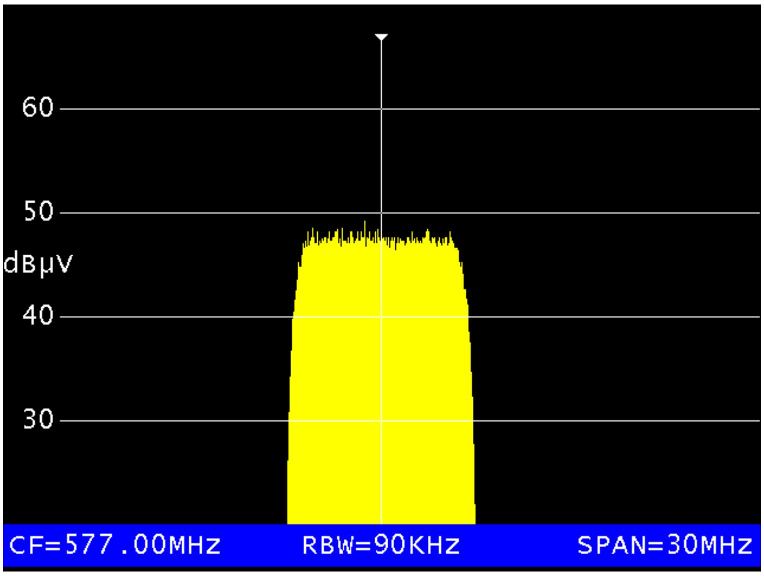
Resulting from the equal distribution of the signal power over a greater range in the spectrum when measuring the level of a digital channel the entire signal bandwidth must always be taken into account.

Level measurement for a section of the digital spectrum would not produce any meaningful result.

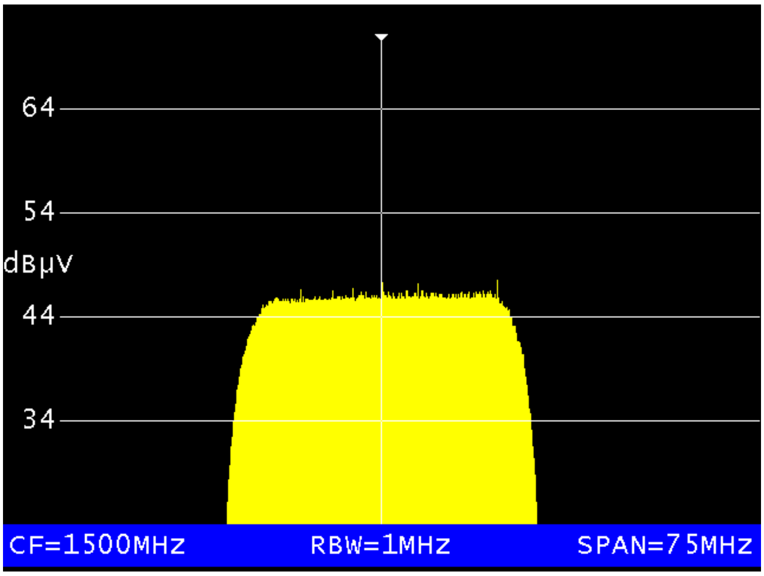
Ideal spectrum of an 8 MHz-wide DVB-T signal:



Ideal spectrum of an 8 MHz-wide DVB-C signal:



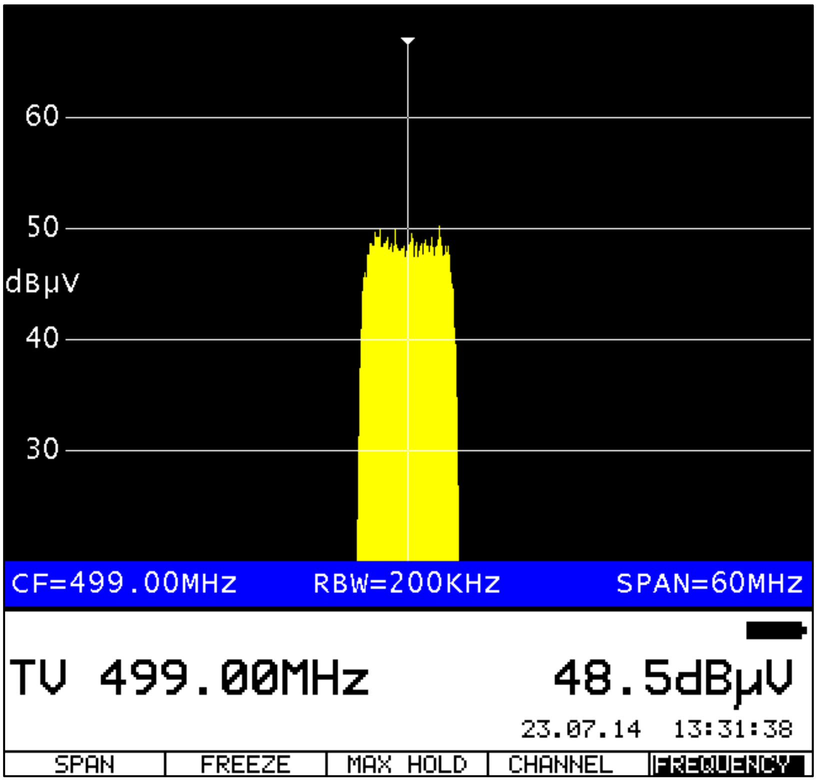
Ideal spectrum of a 33 MHz-wide DVB-S2 signal:



2.3.2 Frequency mode

The frequency modus is the standard mode of operation of a spectrum analyser as is common with professional devices. Here the measurement device makes a sweep as described above over a predetermined span with a given RBW and enters the measured level at this position in the spectrum graph for each measuring point. The level as shown in the measurement device corresponds to value at the cursor position within the measurement bandwidth RBW.

The following picture illustrates this with the example of a DVB-C signal:

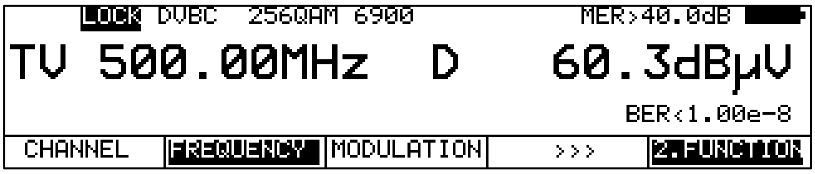


CF=499.00MHz RBW=200KHz SPAN=60MHz

TV 499.00MHz 48.5dBµV

23.07.14 13:31:38

The measurement device shows a level of 48.5 dBµV at the cursor position. However, if the device is tuned to the DVB-C channel (exit analyser) then this results in a level of 60.3 dBµV as the following screenshot shows.


LOCK DVBC 256QAM 6900 MER>40.0dB

TV 500.00MHz D 60.3dBµV

BER<1.00e-8

The measurement bandwidth in the analyser is equal to 200 kHz at a span of 60 MHz. The entire channel bandwidth of 8 MHz is considered for direct measurement of the DVB-C signal, which returns a higher (and correct) result. In the analyser you would get the correct value if you were to divide the 8 MHz channel bandwidth into 40 sub-bands each of 200KHz, then determine the level in each sub-band, and then add up the values logarithmically correctly. To sum up, a normal spectrum analyser is not suitable without further adjustment or mathematical overhead to determine the level of a digital signal correctly.

Assuming that the bandwidth of a signal is known, and that the signal energy is equally distributed over this range, the channel level can be determined using the following formula:

$$Level_{Total} = Level_{RBW} + 10 \cdot log\left(\frac{BW_{Band}}{BW_{RBW}}\right)$$

A section of the total spectrum is measured and a correction value is added to the measured value (in dBµV), which sets the channel bandwidth to the measurement bandwidth logarithmically in proportion. Note: the formula is only valid under the assumptions mentioned above.

The measurement of analogue signals using the spectrum analyser is somewhat easier. Since by definition, only the image carrier is measured in the case of analogue signals you get more meaningful values. For this measurement, you can select a span that operates at 200 kHz RBW. If you move the cursor onto an image carrier, activate the Max Hold function and allow the measurement device to perform several sweeps, you end up with a pretty accurate measured value.

Besides the fact that the shown level value in the analyser only refers to a small portion of the spectrum (RBW), the measurement of the correct level of the digital signal in this diagram is difficult for another reason. The frequency mode is designed so that the sweep time remains manageable. In this mode qualitative assessments are feasible (see below) and level **differences** are recognisable. Various optimisations that are considered for direct measurements of a channel (e.g. waiting for all settling times, averaging, etc.) are supressed in order to allow a short sweep time to provide fast qualitative spectrum assessments.

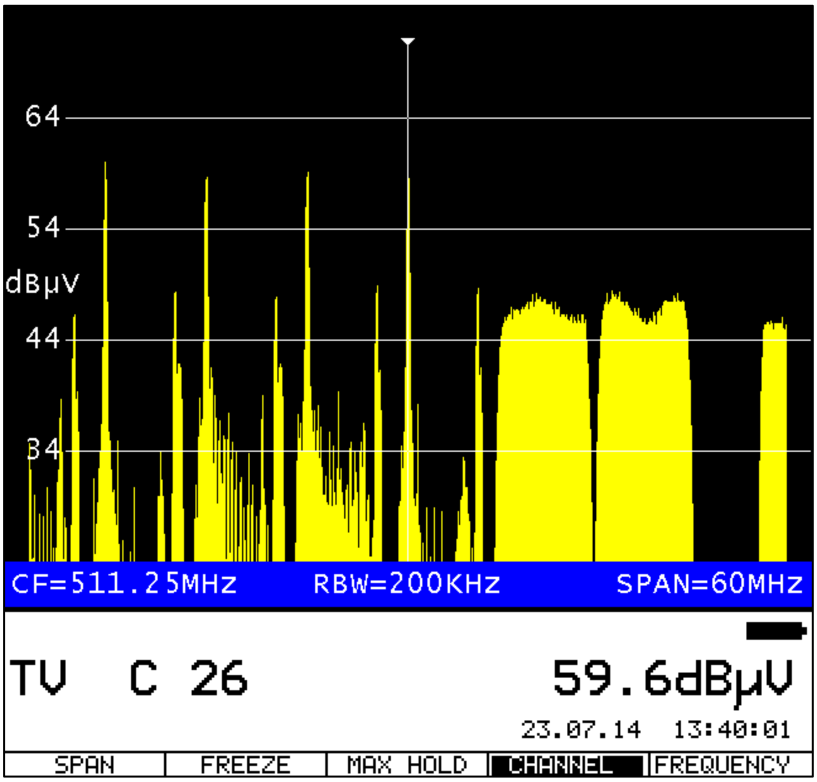
However KWS measurement devices provide a powerful tool, as described in the following Channel Mode section, to measure the real signal levels also when using the spectrum function.

2.3.3 Channel mode

This mode is only available where there is universal channel spacing, i.e. in the TV and DAB ranges.

In the Channel Mode the measurement device recognises automatically whether it is dealing with a signal from an analogue or digital channel. With this information the measurement device also measures the image carrier in the analyser when there are analogue signals (in compliance with Peak Detection over a half frame); for digital signals it adds the level of all spectral parts within a channel.

In the case of an analogue signal the measurement device sets a cursor on the image carrier and measures this. The correct analogue signal level is shown in the analyser or on the LCD measurement display.

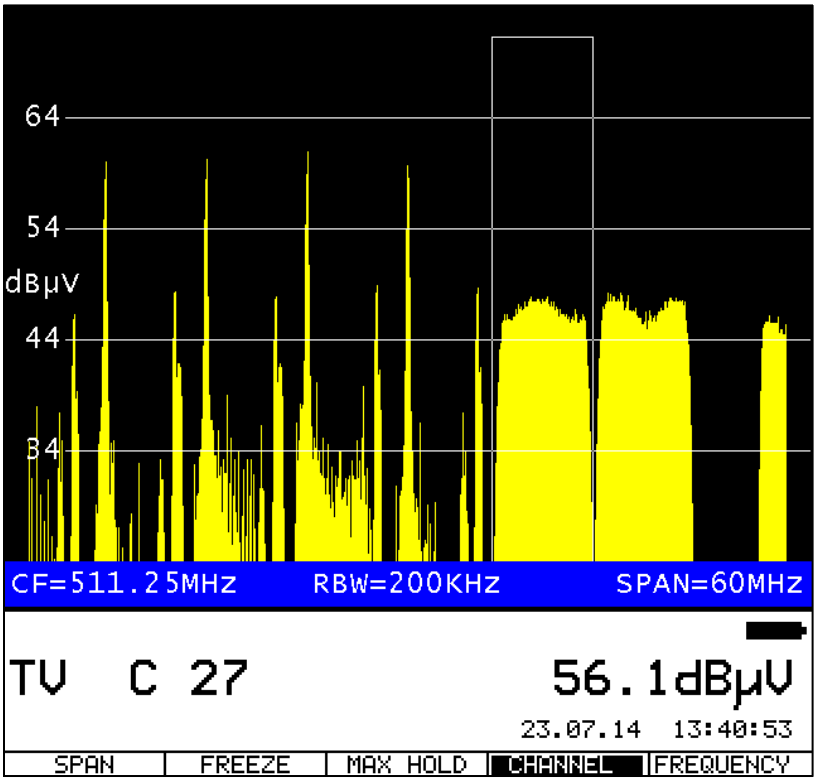


CF=511.25MHz RBW=200KHz SPAN=60MHz

TV C 26 59.6dBµV

23.07.14 13:40:01

For digital signals the measurement device draws a frame around the channel. You can see in the following picture that all the spectral parts of the marked channel lie under the 50 dBµV line, but nevertheless the (correct) channel power of 56.1 dBµV is shown corresponding to the summed total channel level.

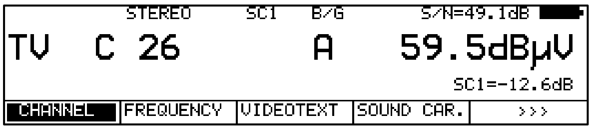


CF=511.25MHz RBW=200KHz SPAN=60MHz

TV C 27 56.1dBµV

23.07.14 13:40:53

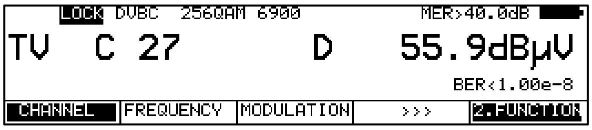
The comparison with the measured value displays in both cases with tuned measuring receiver shows that with activated Channel Mode in the analyser the levels are accurately reproduced.



STEREO SC1 B/G S/N=49.1dB

TV C 26 A 59.5dBµV

SC1=-12.6dB

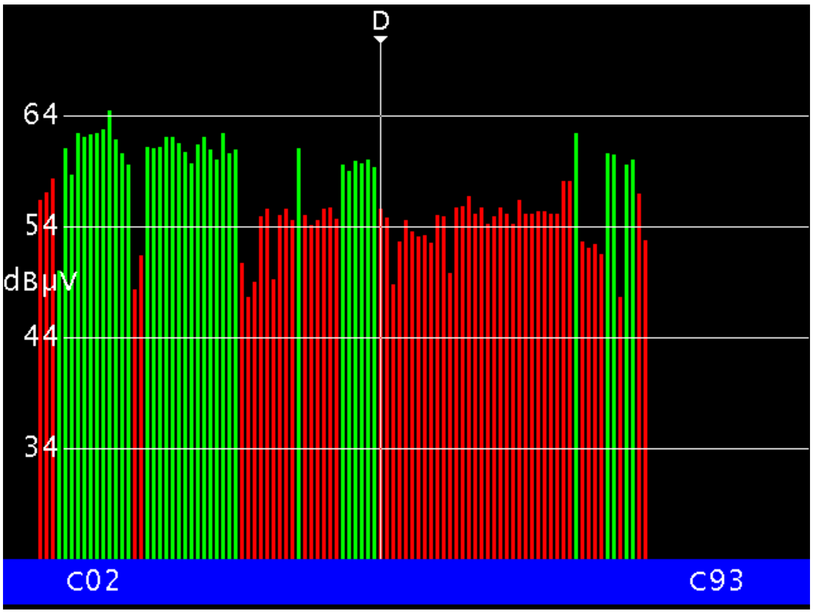


LOCK DVBC 256QAM 6900 MER>40.0dB

TV C 27 D 55.9dBµV

BER<1.00e-8

For the sake of completeness it should be mentioned at this point that the Channel Mode in the Full Span provides a very useful tool. Here analogue and digital signals are differentiated using colour and are level-wise correctly measured. This provides a “levelgram”, which gives a quick overview of the system that is being measured.



2.4 Spectral error images (principle representation)

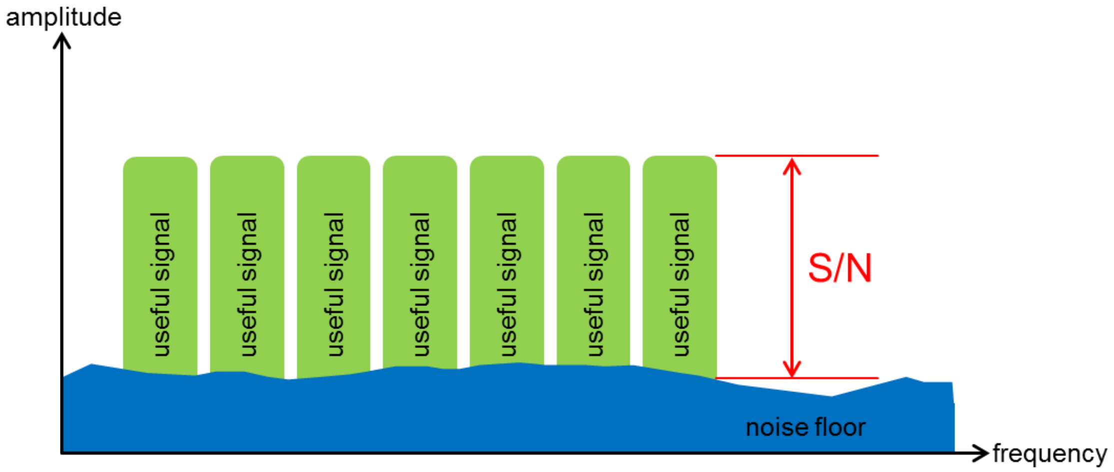
The spectrum analyser is one of many tools in an RF measurement receiver used to measure a signal or a distribution system. The analyser is one among the most important and often under-estimated operation modes of the device. Many errors are not quantifiable but nevertheless can be seen at a glance by the trained eye. If such a case, the impact in other operation modes (MER measurement, S/N measurement, echo plot, TILT measurement, etc.) can be supported by a measured value.

The following sections show principle representations of some error images. It does not claim to be complete.

2.4.1 S/N

The term S/N (Signal-to-Noise Ratio) is generally used hereafter when assuming noise as disturbance variable. This applies both to the RF situation, even if C/N is referred to here, as well as for digital signals where one speaks of MER in the baseband. For spectral observations and with noise as the only available disturbance, these distinctions are irrelevant.

S/N establishes a relationship between the power of a useful signal and the (ever present) noise as disturbance variable. In the spectrum you can – providing you have a sufficiently high noise level or sufficient analyser dynamics - read off the S/N qualitatively as follows.



The formula in this context is as follows:

$$\left[\frac{S}{N}\right]_{dB} = 10 \cdot log\left(\frac{Signal\ power}{Noise\ power}\right) = 10 \cdot log\left(\frac{P_S}{P_R}\right)\ dB$$

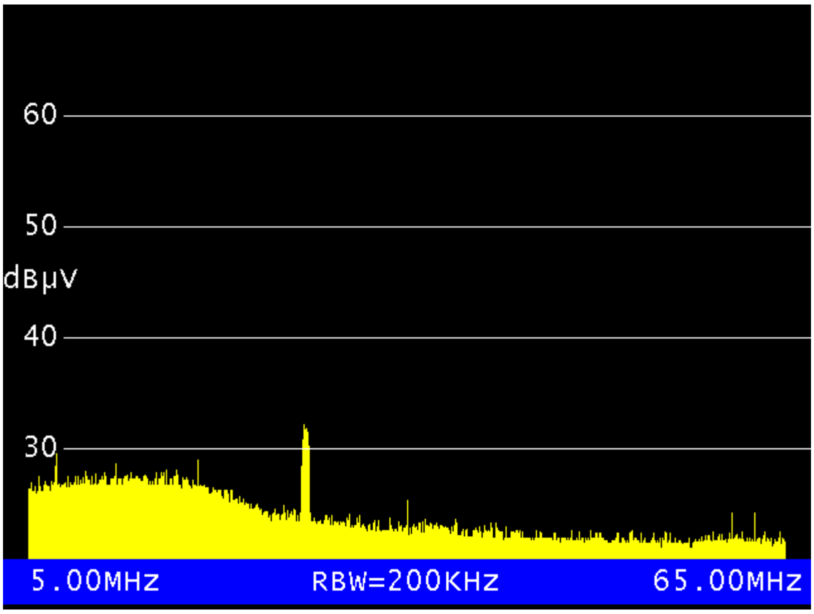
Here the S/N in dB is calculated from the power ratio between the effective signal and interference signal.

The S/N should be as big as possible. The measurement receiver delivers a measurement reading if it is tuned to a channel (as S/N or MER).

2.4.2 Ingress

Interferences in the cable network are known as ingress. In an ideal situation a cable network is RF tight. This means all electromagnetic energy, which is sent from the headend through the cable network, remains within the network. Furthermore, this means that all energy outside the network (RF masts, DVB-T transmitters, baby phones, garage door openers, LTE, and many other sources) remain outside the network. Unfortunately, this ideal situation is encountered seldom in reality. It is quite possible that signals are injected into the cable network disturbing the effective signals there. As Ingress disturbances are often short-lived it is recommended to always operate in Max Hold mode when tracking ingress with the spectrum analyser.

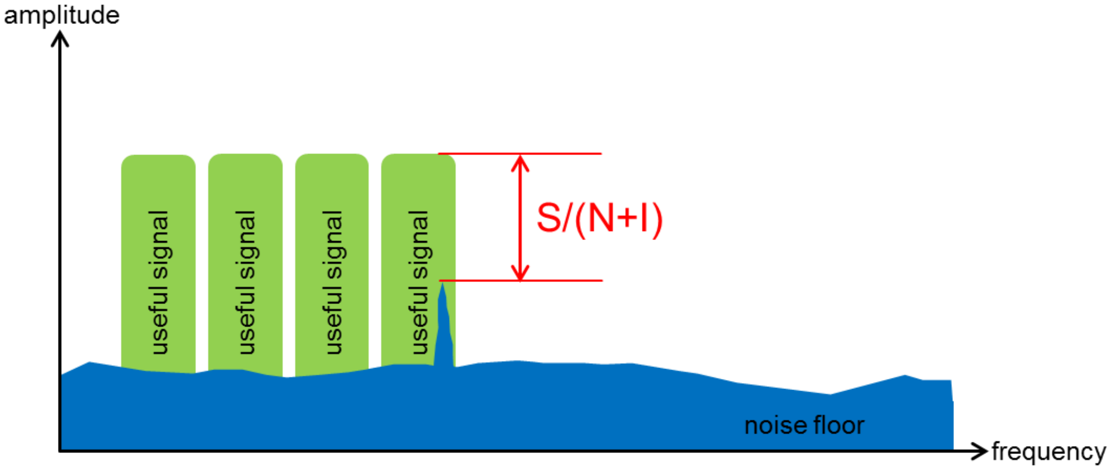
The following diagram shows an ingress disturbance in the return path frequency range.



2.4.3 S/(N+I)

The signal-to-noise-plus-ingress-ratio is defined analogously to the S/N. Here the maximum from combined noise and ingress parts is relative to the signal power. The following applies:

$$\frac{S}{N} \leq \frac{S}{N+I}$$



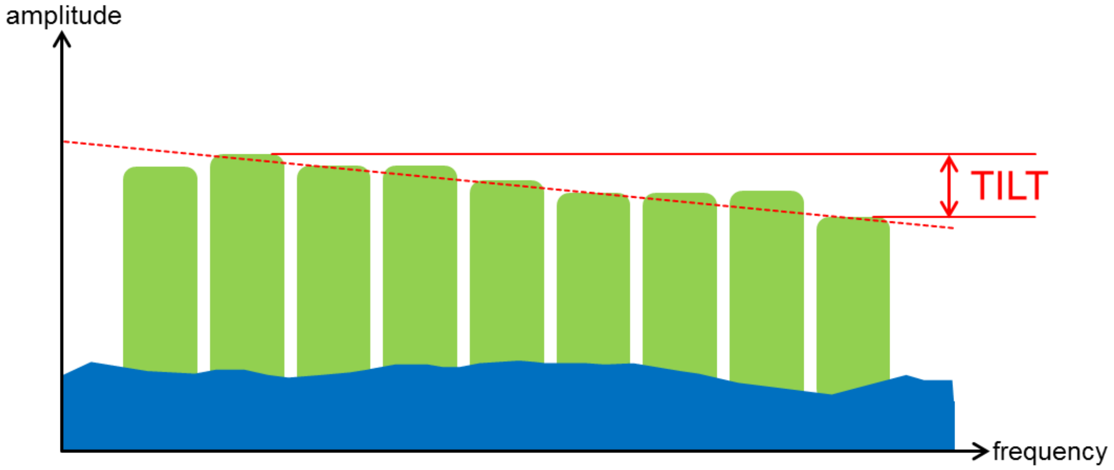
2.4.4 TILT

A TILT is where the levels of the transmission channels in a frequency band fall continuously to a band edge. Generally, this involves the high frequencies, because the cable attenuation rises with the frequency and the amplification of active components sinks with the frequency.

To compensate for this effect, amplifiers, e.g. cable network amplifiers and house amplifiers, have often circuits, i.e. equalisers, which counteract this phenomenon by boosting high frequencies a little more than the lower frequencies.

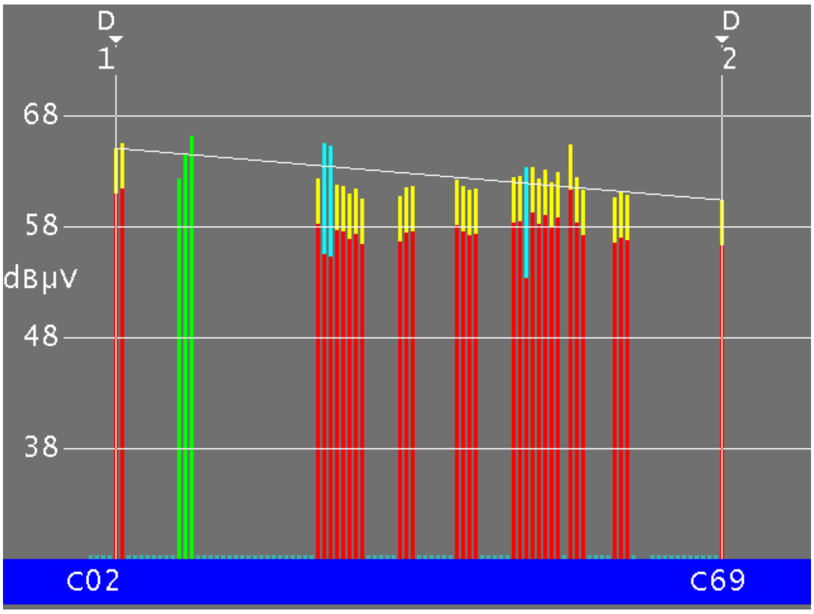
If a slope is detected in the system then these equalisers, if available, have to be correctly adjusted.

The following diagram shows the relationships schematically. In order to be able to give a measurement value for the slope, the level difference of the highest and the lowest channels is normally given in dB.



The KWS measurement receivers for the cable network measurement area provide a very useful tool for tilt measurement. The impact of a slope in a real cable network is overshadowed by the fact that DVB-C and DOCSIS channels in contrast to analogue channels are purposely lowered (normally 10 dB with 64 QAM modulation and 4-6 dB with 256 QAM modulation). That makes it difficult in a spectrum to visually judge which level difference has resulted from a lowering and which because of raised attenuation for high frequencies.

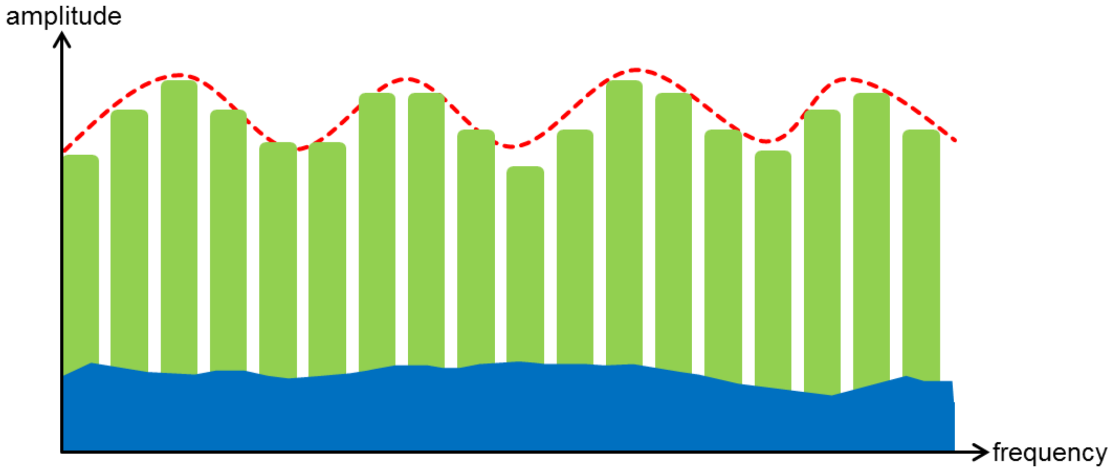
The TILT function of the KWS measuring receivers is based on the channel view in the spectrum analyser with Full Span mode. The channels are also shown colour-coded here and are correctly measured in terms of the level. The TILT function however goes a step further. For digital signals the measurement device automatically detects the modulation and adds a level difference column, also colour-coded, to each channel as in accordance with the QAM order. As a result, all channels are shown normalised on PAL level and the slope can be assessed at a glance. Channels, which are to be used for the TILT measurement, can be selected using comfortable menus and marker functions. The measured values of the slopes can be directly read.



2.4.5 Standing waves

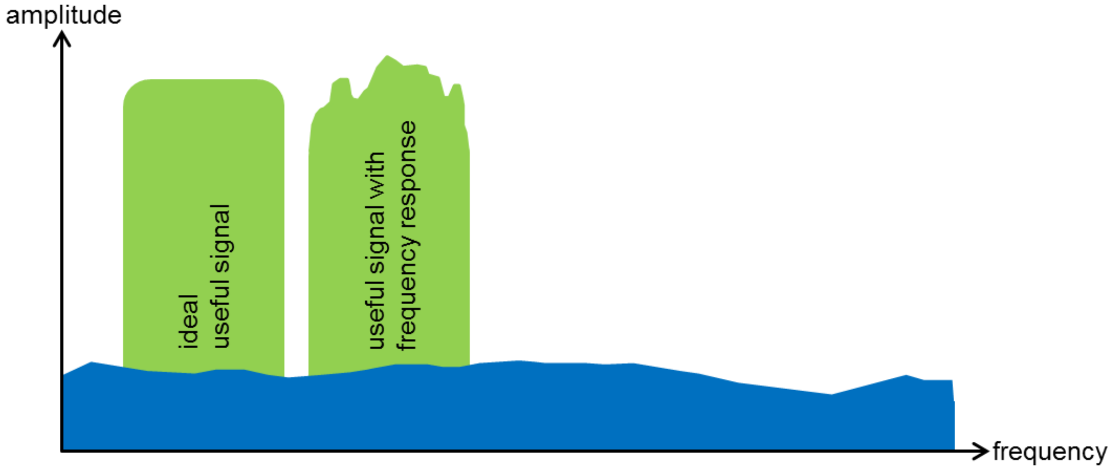
Normally an RF system, e.g. a satellite or cable distribution system, is always adjusted to a constant characteristic impedance. In broadcast technology this value is 75 Ω. This guarantees that all RF energy that is transmitted through the network by the transmitter is 100% absorbed by the receiver. If the condition of a constant characteristic impedance is violated in the network, e.g. by open cables, unterminated sockets, corrosion, cable breakages, faulty connectors, defective active components, etc., a partial reflection of the RF energy occurs at these points.

Depending on the frequency (and thus wavelength) the transmitted signal and the incorrectly reflected signal may either constructively (amplitude increases) or destructively (amplitude decreases) overlap. This effect can be observed in the spectrum.



2.4.6 *Channel frequency response*

A standing wave affects the complete spectrum or at least a large section of it. There are however effects, which produce a significant frequency response within a channel. In the broadband cable world these are so-called micro-reflections. In the case of DVB-T, multi-path propagation and operation of single frequency networks can cause these effects.

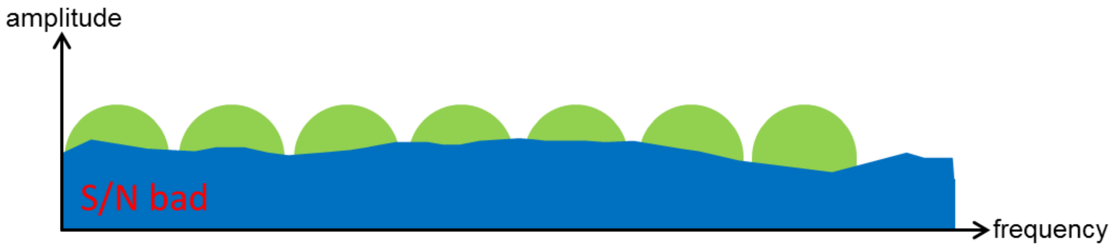


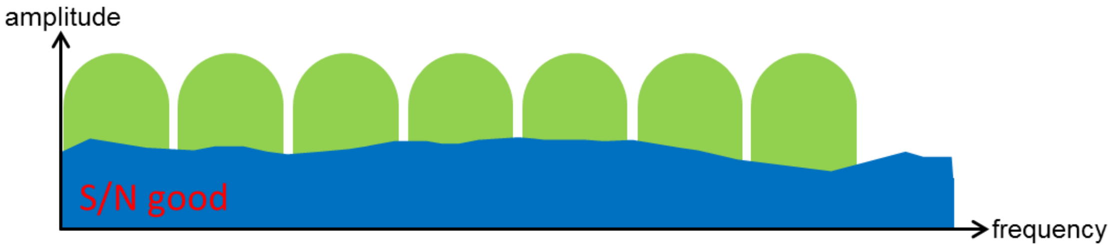
In the case of DVB-C and DOCIS, if detected in the spectrum, the channel frequency response can be quantified as follows. If the measurement device is tuned to a digital channel an equaliser in the demodulator equalises the channel frequency response as far as possible and adaptively (i.e. the equaliser adjusts its parameters continuously to a changing channel frequency response). This equaliser can be deactivated for the AMA 310 measurement receiver. As a result, the impact of a non-corrected channel frequency response on the constellation diagram can be evaluated. Furthermore, the MER reduction caused by the deactivated equaliser is directly related to the frequency response.

Channel frequency response is even easier to quantify for DVB-T. Each DVB-T demodulator also has an integrated equaliser. The pilot carriers embedded in the OFDM signal determine its parameters. The measurement device then generates the so-called echo plot (impulse response) from the equaliser parameters. This graphical tool shows at a glance the reception strength of echoes or farther single-frequency transmitters. The fewer echoes received, and the lower their level is compared to the main reception direction, the less critical the channel frequency response and the better the reception and thus the robustness against other interference such as noise (system reserve).

2.5 Spectrum analyser for installing a satellite dish

If a satellite dish is to be installed the correct satellite must first be found. For this the spectrum is the most important aid. The dish must be adjusted by rotating and tilting so that the digital spectra of xPSK transponders extend as far as possible from the noise, i.e. that a good S/N can be seen on the analyser.





With the spectrum optimised the measurement device is tuned to a channel. Using the NIT table or using a known TV program a check can be made that the correct satellite has been located. It this is not the case then you have to continue with the rotating and tilting of the dish and optimization of the spectrum until the correct satellite has been found.

Only when the satellite is verified and the spectrum has been optimized can the fine-tuning of RF parameters (MER, BER) be continued.

For the sake of completeness it should be pointed out at this point that the spectrum display can also be used to measure cross-polarisation decoupling.

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