Analyzer of Transport Streams in DVB Systems Suitable for Educational Purposes

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***Abstract* — Television, radio and a lot of other multimedia services belong today among the most used sources of information and entertainment. Digitalization allowed television to bring it to end users not only in a high definition quality but also with many other data services. This is the case of digital video broadcasting systems that can distribute video, radio and data directly to users terrestrially, by satellites or by cable systems. In this paper we would like to present how this technology could be included in the educational process so the students could be familiar with its concept in easier way. We analysed actual situation and then implemented a new efficient tool (TS analyser) that allows students to analyse this technology from a DVB transport stream point of view. This tool is presented here with all significant functions.**

I. INTRODUCTION

Television (TV) has undergone a lot of important milestones throughout the years of its evolution starting with a primitive mechanical television (1884) through electronic analog (black and white, colour) televisions to digital television (in standard and high definition resolutions). Digital television provides a new way of video distribution and broadcasting. It is a new media that offers a lot of innovations with a new operation model. The advent of digital television significantly contributes to a convergence of computers, television and Internet. Benefits for customers are noticeable: a treat from a picture in high definition resolutions, audio in CD quality, hundreds of TV channels and plumbless access to a wide range of new services. These digital technologies allow various companies, operators, providers and distributors to offer a variety of useful and profitable services such as a high data rate Internet access, offline as well as online games, video on demand, video and audio (songs) streaming, electronic newspapers and others [1].

Digital television came into being thanks to cooperation among a several companies such as European Telecommunications Standards Institute (ETSI), Digital Video Broadcasting (DVB) consortium (project), the Advanced Television Systems Committee (ATSC) and other. A digital video broadcasting project originated in years 1991 to 1993 and grouped about 80 members. At present time, about 300 organizations and companies maintain this project (consortium) in more than 30 countries and project member portfolio covers electronic device producers, network operators, broadcasters, software companies and regulatory bodies [2].

DVB was first adopted in Europe (United Kingdom). Currently, except Europe DVB is also used in Australia, Asian, African and American countries.

If we want to allow understanding the DVB technology for students in the educational process and to prepare good experts in this area [3] suitable online/offline educational materials are needed. These materials should contain a technical description of the DVB technology as well as practical demonstrations. The practical demonstrations are based on hardware and software applications which can enable students to analyse a DVB transport stream with all its components in a comprehensible form.

Therefore, this paper in Section II analyses actual situation in software DVB analyser applications, states final requirements for our educational process and explains why we decided to implement a new solution. Section III briefly introduces the DVB technology and its main terminology. And Section IV contains a description of main functionality of our application – TS analyzer. Section V concludes the paper.

II. PROBLEM SPECIFICATION

For practical demonstrations in the DVB technology we propose a simple laboratory (as can be seen in Fig. 1). There are 4 PC stations where students can study in groups and work out assignments. Each post consists of a PC station (desktop or laptop) and DVB device (internal or external) as well as software environment equipped by an efficient application (tool) for the DVB transport stream analysis. All DVB devices are connected to an antenna receiving terrestrial or satellite signals. In this paper, we are going to concentrate mainly on software tools that allow students to analyse a DVB signal.

We investigated 4 existing software solutions enabling users to analyse DVB transport streams: Streamguru MPEG & DVB Analyzer [4], MPEG-2 Transport Stream

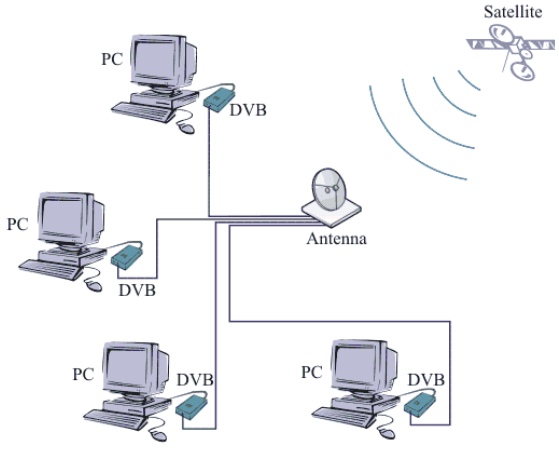

Figure 1. Example of a laboratory for DVB stream analysis

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packet analyser [5], DVBStreamExplorer [6] and dvbsnoop [7]. Table I summarises our comparison of all these tools. From the comparison (and Table I) it is clear that Streamguru MPEG & DVB Analyzer and DVBStreamExplorer are very efficient tools with a lot of functions. They support the detailed live and offline analysis of DVB signals (and tables). However, these tools must be purchased. All 4 tools support terrestrial and satellite DVB signals. MPEG-2 Transport Stream packet analyser doesn't allow live analysis and its functions in table analysis are also limited. Dvbsnoop supports the live analysis but it doesn't provide a graphical interface and has also limited functionality. We can conclude that none of these tools meets our original requirements such as: an intuitive graphical user interface, no limitations in DVB table's analysis, a support for live and offline analysis, Windows platform, and the free of charge licence.

Therefore, we decided to implement our own tool with the functionality that can be summarised as follows:

- online (live) and offline access and analysis of DVB transport streams,
- complex analysis of all program specific information tables and service information tables,
- gathering the statistics related to DVB signals and transport streams (bit rates, lists of services, errors, …),
- playback of video elementary streams,
- displaying table components and measured data in suitable form (charts, tables, tree structure),
- export of measured data,
- possibility to see and analyse a content of individual transport packets,
- recording the complete transport streams to a file,
- detailed logs about a tool operation,
- intuitive and comfortable graphical interface,
- help and helpful tips to understand technical terminology and parameters,
- Microsoft Windows platform,
- support for a wide range of DVB devices (internal or external).

TABLE I.
THE COMPARISON OF EXISTING DVB TOOLS

Tool	Streamguru MPEG & DVB Analyzer	MPEG-2 Transport Stream packet analyser	DVB Stream Explorer	dvbsnoop
Licence Price	Trial 239 €	free	Trial 40 € (99,99 €)	free
Platform	Windows	Windows	Windows	Linux
Standards support	DVB	DVB, AVCHD	DVB, ATSC, ISDB	DVB
Live / offline analysis	yes / yes	yes / no	yes / yes	yes / yes
Supported devices	Dektec DTAPI compatible, BDA compatible	-	Dektec, SkyStar2, BDA compatible	DVB API compatible
Graphical interface	yes	yes	yes	no
Multimedia content playback	yes	no	no	no
MPEG-2 tables analysis	yes	yes (limited)	yes	yes (limited)

III. DVB SYSTEM

The DVB technology enhances an analog TV technology by a picture quality, data services and interactivity. It provides three basic (core) services: video broadcasting (television in standard or high definition resolutions), audio broadcasting and data broadcasting. Data services can be divided into two groups: interactive (a separate return channel is used by users to choose and control content), e.g. Internet access or electronic business or banking and pseudo-interactive (content is stored in end device memory and users can select and browse it), e.g. webcasting or games distribution.

DVB represents a set of open standards maintained by DVB Project (consortium) covering broadcasting of digital video or in general digital TV. These standards are published by ETSI, CENELEC and EBU. Therefore, they are internationally accepted. DVB standards cover all aspects related to broadcasting and processing of digital video and audio at a physical and data link layer of a communication model. A lot of these aspects closely relate to transmission media used for broadcasting (terrestrial, satellite or cable). We mention only a few of those standards [8]:

- DVB-S – broadcasting digital TV via satellite
- DVB-T – broadcasting digital TV terrestrially
- DVB-C – broadcasting digital TV via cable systems
- DVB-RCS/RCT/RCC – return (interaction) channel via satellite/terrestrial/cable
- DVB-H – broadcasting digital TV to handhelds
- DVB-Data – transmission of high speed data services
- DVB-SI – defines a service information (metadata)
- DVB-CSA – defines a common scrambling algorithm
- DVB-CI – defines a common interface (CI) between a removable conditional access module and receiver

DVB-S, DVB-T and DVB-C are the most used technologies for accessing the digital content. This multimedia content is grouped and transmitted through MPEG transport streams. DVB technology adopted an MPEG-2 compression standard [9] because it supports several video qualities and resolutions as well as it provides high flexibility. An MPEG-2 systems layer defines how various elementary streams representing one or multiple programmes are multiplexed together. A programme represents a single broadcasting service or channel. The elementary streams can carry video, audio, data, and other information. This multiplexing process produces a single (multi-programme transport) data stream that can be stored or transmitted via a physical medium. In general, the MPEG-2 systems layer performs more functions: multiplexing, packetization, timing and synchronization, and conditional access.

The elementary streams can carry the MPEG-2 compressed video and audio, data, timing and system

information, conditional access information and other programme related data. They represent components of the programme. The simplest type of a programme is a radio service that consists of a single elementary audio stream. On the other hand a classical television service consists of three elementary streams: one stream carries coded video, second stream carries coded stereo audio and third contains teletext. An uncompressed digital video stream consists of a sequence of frames called presentation units. The MPEG-2 coder encodes and compresses every presentation unit making an access unit.

The MPEG-2 multiplexer does not directly multiplex sequences of the access units from its inputs. All elementary streams consisting of the access units are transformed into so called packetized elementary streams (PES) consisting of PES packets [10]. Every PES packet contains a header and a payload. The payload is a field where data of the original elementary stream are grouped in one after another. When the elementary streams are in a form of packetized elementary streams they are multiplexed (grouped) by the MPEG-2 multiplexer with all other special information to form a resulting contiguous byte data stream. Fig. 2 depicts a principle of multiplexing in the MPEG-2 systems layer.

The MPEG-2 multiplexer can produce two types of multiplex streams: a programme or transport stream (TS). The programme stream is intended for the storage and retrieval purposes of digital content from storage medium (e.g. DVD) and it relies on error-free environments. Unlike the programme stream the transport stream enables to multiplex more programmes and it is not so much susceptible to errors because it is protected by FEC (Forward Error Correction) code. Therefore, TS is suitable for broadcasting via terrestrial or satellite environments. The other difference is that TS consists of transport packets with fixed length of 188 bytes. In the transport stream each transport packet is equipped by a PID (Packet Identifier) value specifying an elementary stream it belongs to.

As can be seen from Fig. 2, the MPEG-2 multiplexer multiplexes elementary streams with other information (time stamps, tables, scrambling support, private data channels). In this paper we will only pay attention to tables. Tables contain service information data which identify programmes within a multiplexed signal (multiplex) as well as their elementary streams, network parameters, etc. There are program specific information (PSI) and service information (SI) tables [11]. The PSI tables are:

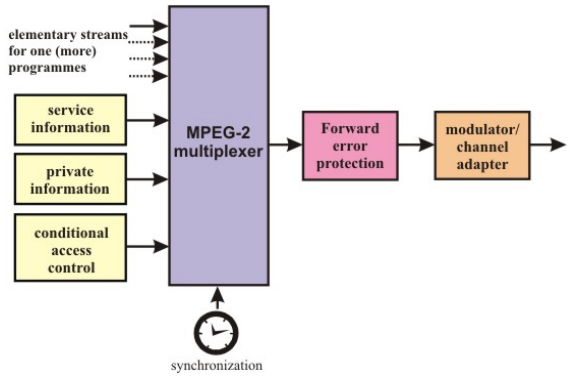

Figure 2. Multiplexing in the MPEG-2 systems layer

- Program Association Table (PAT) – complete list of all programmes in TS.
- Program Map Table (PMT) – each programme is assigned by its PMT table where a list of all its elementary streams is saved.
- Conditional Access Table (CAT) – it contains information about scrambling system.
- Network Information Table (NIT)

DVB SI tables carry information about a network (NIT), detailed description of programmes (SDT, Session Description Table), a structure of grouping services (BAT, Bouquet Association Table), control information for set-top-boxes/video recorders (RST, Running Status Table), time and date information (TDT, Time and Date Table) in the GMT format or in different time zone (TOT, Time Offset Table), tables to replace previous (invalid) tables (ST, Stuffing Table) and information about events in TS e.g. the electronic program guide (EIT, Event Information Table). More details about these tables can be found in [12] and [13].

IV. Description of TS Analyzer Tool

In this section we would like to describe a tool called TS analyzer we developed [14]. Its basic functionality and graphical user interface will be introduced.

A. Main window

Fig. 3 depicts a main window of our tool. As can be seen it is divided into several parts. At the top there is menu bar with all functions you can use to control this tool (e.g. data loading or saving to XML file, selection of a signal source, starting or stopping the signal scan, recording the transport stream, export of measured data to the file, etc.). Below the menu bar 5 icons for important (frequent) functions are placed (e.g. to set the signal source, control the signal scan, to access a configuration window, etc.). Below these icons you can set a source of the transport stream (local file, transponder, multiplex) and in case of correct value the user can choose one of available services – TV or radio channels (e.g. TV JOJ channel). On the right side of all control elements mentioned so far there is another control element consisting of four numbered buttons which control a basic structure (look) of the main window. Using these buttons you can show or hide particular sections. It means that the main window contains four meaningful sections. Students can organize them (hide or show) and save the actual arrangement. Each section has a few panels (tabs). They can be closed or opened in a new window enabling the students to set arrangement of this tool based on their requirements. At the bottom of the main window a status bar is situated. It informs the students what operations this tool is just performing. It also depicts information about the signal (its availability, strength and quality).

Now, let's take a look at the section marked (5.) in Fig. 3. There are three panels there the user can analyse. The *Video* panel plays a video of the selected TV service. Other two panels are shown in Fig. 4 and they deal with bit rate statistics. The *Barview* panel allows students to see minimum, maximum and average values of transmission bit rates for particular elementary streams identified by PID values. It is clear that elementary streams with PID 2202 and 2102 carry video data. Similar information is given by the *Bitrate View* panel. Charts in these panels

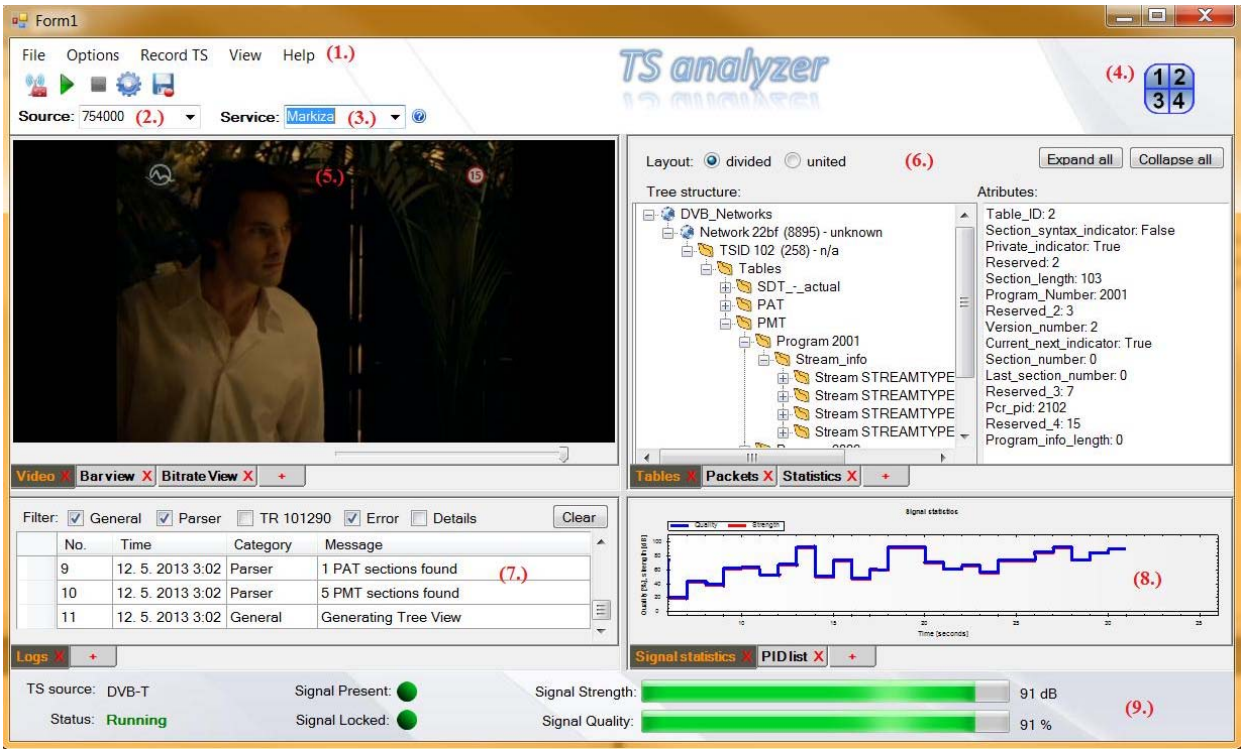

Figure 3. Main window of the tool TS analyzer

depict real transmission bit rates of particular elementary streams as a function of time distinguished by the colour. All bit rate functions are drawn in one chart so they give altogether a total bit rate for given multiplex. It is possible to zoom in these charts as well as save, print or export data to the Excel program.

More detailed information for every programme in a multiplex can be found in the section marked by (6.) in Fig. 3 containing three separate panels. The *Tables* panel provides students with all PSI and SI tables. The student can see here all programme and service specific information which are displayed in a tree structure. All table attributes and values can be shown in the left or right part of this panel. When the student needs to analyse some transport stream packets there is the *Packets* panel available for this purpose. This function can be performed on a saved sample of selected transport stream. This panel (Fig. 5) allows seeing inside any of 188 byte long packets, i.e. to see all their bytes (left top part of the panel). The packet analysis is simplified so the students can study a header, an adaptation field and a payload of given packet based on names of all defined fields. It is possible to show packets in packet by packet mode or just go to concrete one. Third panel in this section the *Statistics* panel brings a view on error statistics of the transport stream. This panel is depicted in Fig. 6 and it summarizes level of errors based on recommendation ETSI TR 101 290. Error indicators are divided into three priorities. The number of errors for each indicator is determined. If student wants to know more about errors there is button (+) available that opens a new window with detailed information. The students can even browse all problematic packets and

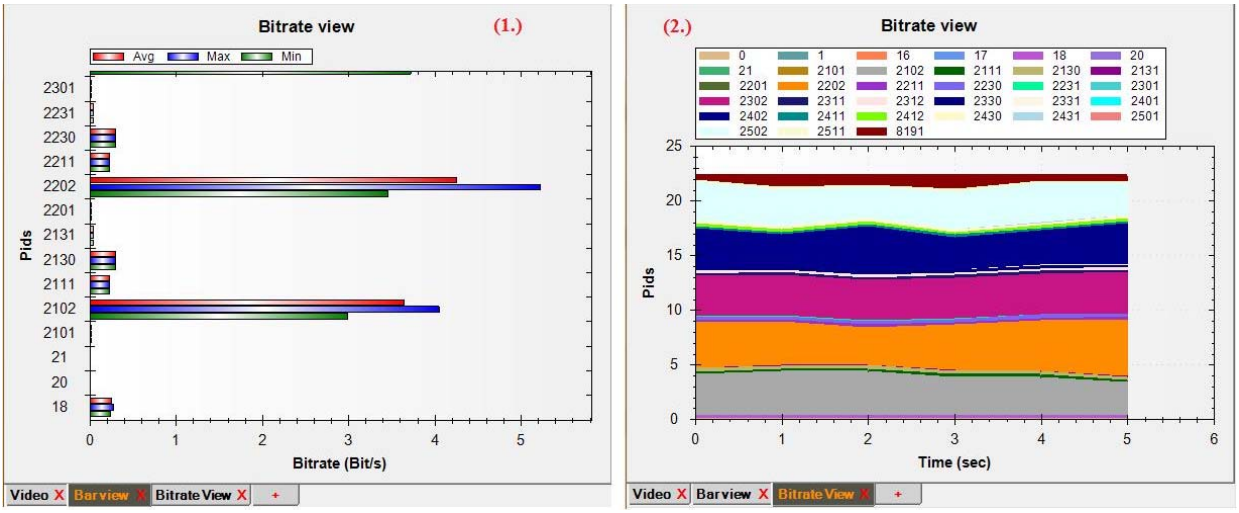

Figure 4. The *Barview* and *Bitrate View* panels

analyse error details.

Third section contains one panel in default. It is called *Logs* panel and it displays significant logs about application operation. It is possible to choose what logs are going to be displayed. Each log contains its time information when an event occurred. All logs (entries) can be sorted or deleted as well as exported to the Excel or text files.

Last section starts with two panels – *Signal statistics* and *PID list* panel. The *Signal statistics* panel (Fig. 3 (8.)) displays simple chart with two functions for real time values of the signal quality and strength when the DVB (T or S) device is a source of the signal. The chart is updated every second. The *PID list* panel is very important and helpful because it provides the list of all packet (elementary stream) identifiers in a transport stream (Fig. 7). The student can identify a type and short description of each elementary stream whether it is a table or other information or video or audio service and they are also distinguished by the colour.

As was already mentioned above the student can change the arrangement of these section (hide or show them) and he can also add other panels in them. There is button with red plus sign to do that. When it is clicked a new window opens. Here the student can choose any of existing panels and add it to any section in the main window.

B. *Signal source window*

In the beginning of tool start it is necessary to set a source of the signal (transport stream) for further analysis. Using the first icon on main window a new window is opened (Fig. 8). As can be seen there are three sources for a DVB signal: a local file (.ts file), DVB-T or DVB-S device (internal or external). In the case of a local file the offline analysis can be performed and one or more input files with (recorded) transport streams can be chosen. In the case of DVB-T or DVB-S input devices the parameter windows look similarly here only latter one will be described. First step is to set a device. Then the student has to set specific parameters, test the signal and start to scan for real transport streams (multiplexes). It is possible to scan for one multiplex (Fig. 8 part (3.)) or the student can manually add multiple signal frequencies (of satellite transponders) or import them from a file that can be generated from information available in Internet. In this case a set of frequencies can be tested and scanned. In

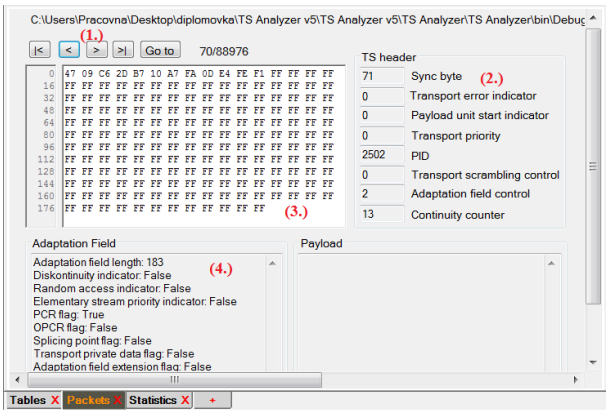

Figure 5. The *Packets* panel

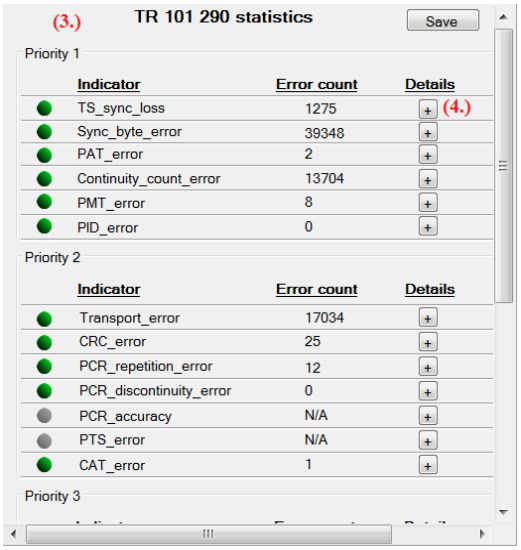

Figure 6. The *Statistics* panel

both cases it is possible to set whether PSI/SI tables should be analysed and statistics evaluated. Scanning can be realised once or in a loop.

C. *Configuration and Help*

TS analyzer enables the students to set a lot of configuration parameters. They are divided into four groups:

- General settings (logs and analysis parameters),
- View/layout settings (basic layout of the main window),
- Tables settings (table types to be analysed and timeouts),
- Storage settings (storage folders, recording parameters).

In order to simplify the laboratory work with this tool for students extended help is incorporated. It is available from the main menu bar. However, it is also available as

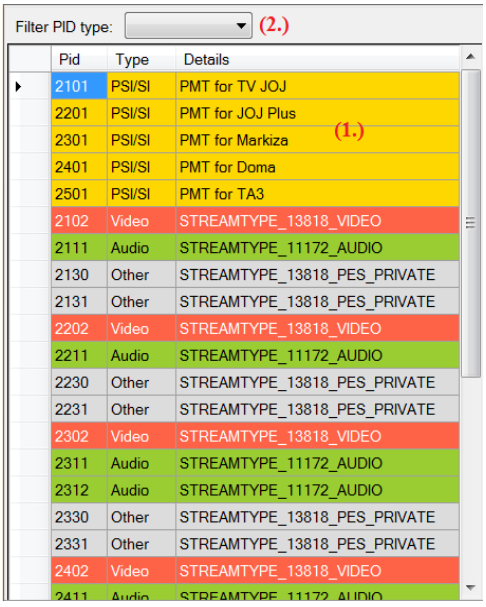

Figure 7. The *PID list* panel

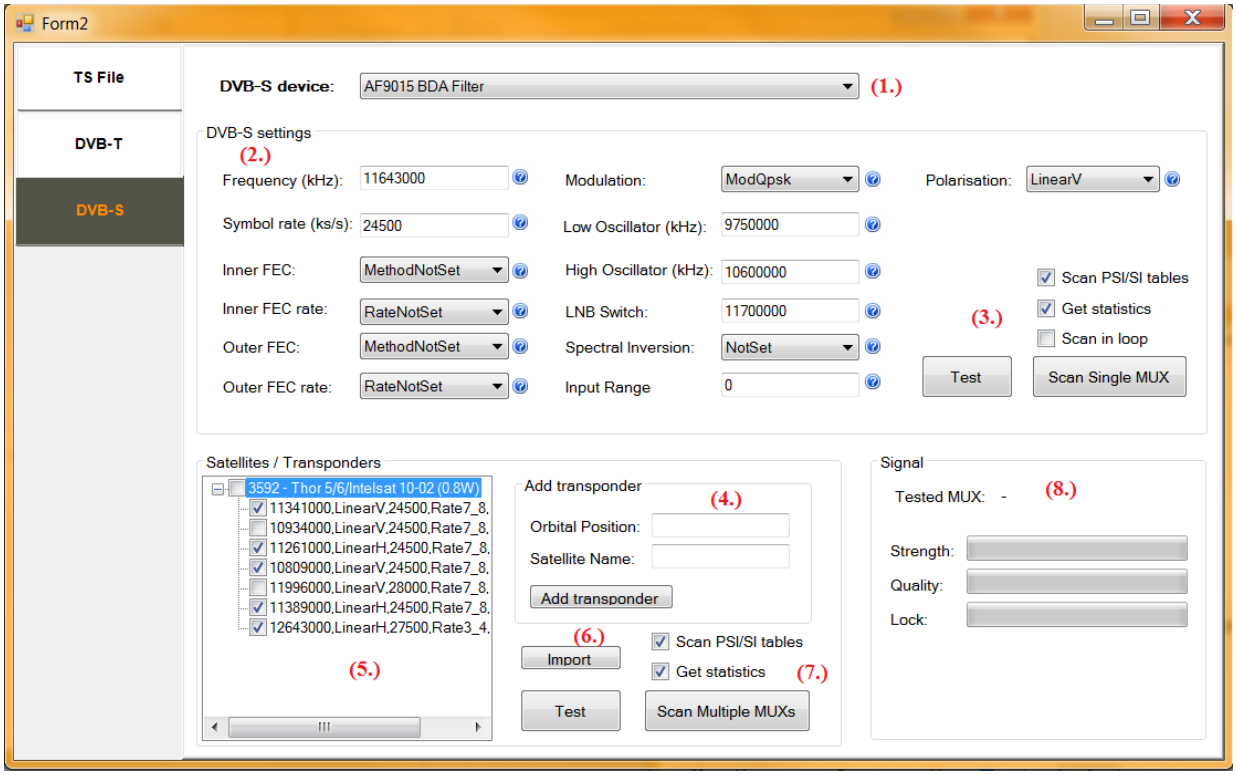

Figure 8. The selection of a signal source (DVB-S device) and its parameters

helpful definitions or explanation tips throughout the entire tool via icons with „?“ sign.

V. Conclusion

This paper is oriented to the area of digital video broadcasting systems with a main focus on integration of this topic in the educational process. To allow students to fully understand this technology a suitable software tool is necessary for practical demonstrations of multiplexing process and a structure of transport streams in DVB systems. We analysed existing tools and implemented a new tool *TS analyser* that can be used for this purpose and that enables students to see and analyse elementary streams and tables within the final DVB MPEG-2 transport stream. Main part of this paper presents important functions of our tool.

Acknowledgment

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