



Recommendation ITU-R SM.1600-3
(09/2017)

Technical identification of digital signals

SM Series
Spectrum management



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Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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Series of ITU-R Recommendations

(Also available online at <http://www.itu.int/publ/R-REC/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2017

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RECOMMENDATION ITU-R SM.1600-3

Technical identification of digital signals

(2002-2012-2015-2017)

Scope

This Recommendation describes various processes, methods and tools for technical identification of digital signals. It provides a collection of methods and tools from many sources, and recommends application for different use cases. Not all of the tools described are required to be used in order to be in compliance with this Recommendation. It does not provide in-depth explanation of the algorithms or design features of the hardware or software tools.

Keywords

Signal identification, signal analysis, digital signals

Abbreviations/Glossary

ADC	Analogue to digital converter
AM	Amplitude modulation
ASK	Amplitude shift keying
CAF	Cyclic autocorrelation function
CDMA	Code division multiple access
EVM	Error vector magnitude
FDE	Frequency domain equalization
FDMA	Frequency division multiple access
FM	Frequency modulation
FSK	Frequency shift keying
GMSK	Gaussian minimum shift keying
GSM	Global system for mobiles
I/Q	In-phase and quadrature
OFDM	Orthogonal frequency division multiplexed
PRF	Pulse repetition frequency
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
SC	Single carrier
SCF	Spectral correlation function
SNR	Signal-to-noise ratio
TDMA	Time division multiple access
UWB	Ultra wide band
VSA	Vector signal analyser

Related ITU Reports

Report ITU-R SM.2304

NOTE – In every case the latest edition of the Report in force should be used.

The ITU Radiocommunication Assembly,

considering

- a) that the use of radio grows steadily;
- b) that digital signals are being widely used;
- c) that an increasingly large number of devices can be used without a licence or certification process, making it difficult for an administration to identify the source of an emission;
- d) that sharing of the same spectrum by several radiocommunication technologies is an emerging trend;
- e) that the interference complaints involving digital emissions are often difficult to resolve;
- f) that technical identification often is an essential prerequisite to any measurement on digital signals with complex waveforms as used in many digital communication systems;
- g) that signal databases are available which can associate modern digital signals with their respective external and internal parameters;
- h) that new analysis and identification tools and techniques are available, that can lead to recognition of the nature of an unknown signal or to complete identification of modern digital standards,

recommends

- 1 that digital signals should be identified in the following order:
 - general identification process based on signal external characteristics;
 - identification based on the signal internal characteristics (modulation type and other internal waveform parameters) when low/partial *a priori* knowledge is available about the signal;
 - identification based on correlation with known waveform characteristics when strong *a priori* knowledge is available about the signal;
 - identification confirmed by signal demodulation, decoding or comparison with known waveform characteristics (if not already used in the identification process);
- 2 that the collection of processes, methods and tools described in Annex 1 be considered for use.

Annex 1

1 Introduction

This Annex describes steps designed to be used either stand-alone or together in sequence to identify a digital signal of interest. The information is intended to provide fundamental, practical and logical advice on the handling of standard modern digital signals. The text addresses the use of external signal parameters, offers advice on the analysis of internal signal parameters to more completely analyse

the signal; and describes the use of software tools and techniques to positively identify a standard modern digital signal. The array of tools discussed in this Annex are examples that could be used for identification of digital signals, but not all are required to be used in order to be in compliance with this Recommendation, and in fact equipment available to a particular monitoring service may not include all of these tools. The tools and techniques discussed in this Annex generally involve interaction between the operator and the system because most systems do not automatically perform the process of identifying digital signals.

While some modern spectrum analysers have the capability to characterize signals, many do not have the capability of preserving and providing the in-phase and quadrature (I/Q) signal data that are useful for more advanced analysis of signal internals. While the focus of this Annex is on vector signal analysers, monitoring receivers, spectrum analysers and spectrum monitoring systems possessing signal analysis features may in some cases be used as well.

2 Definitions of digital signals and methods for signal analysis and identification

Standard modern digital signals: These signals typically include the following modulation schemes and multiple access formats:

- Amplitude, phase and frequency shift keying (ASK, PSK, FSK) including Minimum shift keying (MSK).
- Quadrature amplitude modulation (QAM).
- Orthogonal frequency division multiplexed (OFDM).
- Time division multiple access (TDMA).
- Code division multiple access (CDMA).
- (Coded) Orthogonal frequency division multiplex (Access) (C)OFDM(A).
- Single carrier frequency division multiple access (SC-FDMA).
- Single carrier frequency domain equalization (SC-FDE).

Classify; signal classification: The classification of signals refers to the process of sorting signals by parametric features such as frequency plan, bandwidth, spectral shape, duration, occupancy (examples of signal externals), as well as modulation format and symbol rate or baud rate (examples of signal internals). The classification process does not include a determination of the original content of the signal, but rather is intended to help the operator determine the type of device emitting the signal. For example, the process can provide information to determine if an emitter is an uplink or downlink, a control channel or traffic channel. While signal externals can usually be measured with a spectrum analyser, classification of the modulation usually requires I/Q time-series data and special software algorithms. With the proper setup and right conditions (adequate SNR and acquisition time, etc.), modulation classification software may work automatically to report the correct format and symbol rate. However, in many cases, classification of the modulation requires operator intervention as described in the steps outlined in this Annex.

Signal identification, signal analysis systems and software: This is a class of systems or software that can provide positive identification of a modern digital signal by correlating the signal waveform to a library of known patterns such as pre-amble, mid-amble, guard time, synchronization word, synchronization tones, training sequences, pilot symbols and codes, scrambling codes and by correlating the demodulated or decoded signal to a library of known patterns such as signalling data in broadcast channels.

I/Q signal data: I/Q refers to in-phase and quadrature signal data. The I/Q data resulting from sampling of a signal allows all of the amplitude, frequency and phase information contained in the

signal to be preserved. This allows the signal to be accurately analysed or demodulated in different ways, and is a common method of detailed signal analysis.

Modulation recognition software: This is software that can operate on raw I/Q or audio demodulated recordings and estimate signal characteristics that include:

- Centre frequency and frequency distance between carriers;
- Signal bandwidth;
- Signal duration and inter-pulse duration (when impulsive);
- Modulation class: single or multiple carrier, linear or non-linear;
- Modulation format;
- Symbol rate;
- Signal-to-noise ratio (SNR)¹;
- Signal specific patterns (such as synchronization/pilot tones, guard times, guard intervals, frame structure).

Vector signal analysers (VSA) and VSA software: Instrument VSAs combine either super-heterodyne technology or direct conversion hardware with high speed Analogue to Digital converters (ADCs) and Digital signal processing (DSP), Field programmable gate arrays (FPGA) or embedded General programmable processors (GPP) to perform fast, high-resolution spectrum measurements, demodulation, and advanced time-domain and spectrum-time-domain analysis. VSAs are especially useful for characterizing complex signals such as burst, transient or digitally modulated signals used in communications, video and broadcast. They can provide users with the ability to collect raw I/Q data on signals of interest, modulation recognition capabilities and signal identification capabilities such as defined above. VSA software may or may not control a physical receiver. However, in all cases, it allows the user to analyse raw I/Q data either from a receiver or from files.

Further, VSA software typically provides pre-set configurations or signal templates to demodulate and decode standard digital communications formats (listed in section 6). Users can make use of these templates to easily validate the format of signal types being analysed to confirm that they match signal characteristics of the type licensed to a frequency band. Users can also add new or modify existing signal formats.

Monitoring receiver: A monitoring receiver selects a radio signal from all the signals intercepted by the antenna to which it is connected, and reproduces at the receiver output the information transmitted by the radio signal, while providing access to measurement of the detailed characteristics of the signal. This is typically accomplished by either:

- access to intermediate steps in the signal chain, or
- in most modern receivers, by recording or providing as an output, the complete amplitude and phase characteristics (usually by sampling and saving the I/Q data).

Error vector magnitude (EVM): The error vector is the vector difference at a given time between the ideal reference signal and the measured signal. Expressed another way, it is the residual noise and distortion remaining after an ideal version of the signal has been stripped away. EVM is the root-mean-square (RMS) value of the error vector over time at the instants of the symbol (or chip) clock transitions.

¹ While this is not a common modulation parameter, it is often provided by modulation recognition software.

3 Steps to identify a digital signal

3.1 Evaluate signal externals

The first step in identifying a digital signal is to use the simplest approach. This involves comparing the signal's "external" parameters to the Monitoring Service's licensed signal database and frequency plan. External signal parameters include:

- Centre frequency and frequency distance between carriers;
- Signal bandwidth;
- Spectral shape;
- Signal duration (when impulsive or intermittent);
- Frequency shift.

Visual inspection and matching of the signal of interest to the Monitoring Service's license database provides a good start to identifying a digital signal of interest. If the signal matches all of the external parameters, chances are high that a correct identification can be made without further analysis.

An example of a Frequency Allocation Table is shown in Table 1. The table provides a general description of the services licensed to operate in the band, the operational parameters, signal bandwidths and channelization. These can all be used to match external signal parameters and make an initial assessment of the identity of the signal of interest.

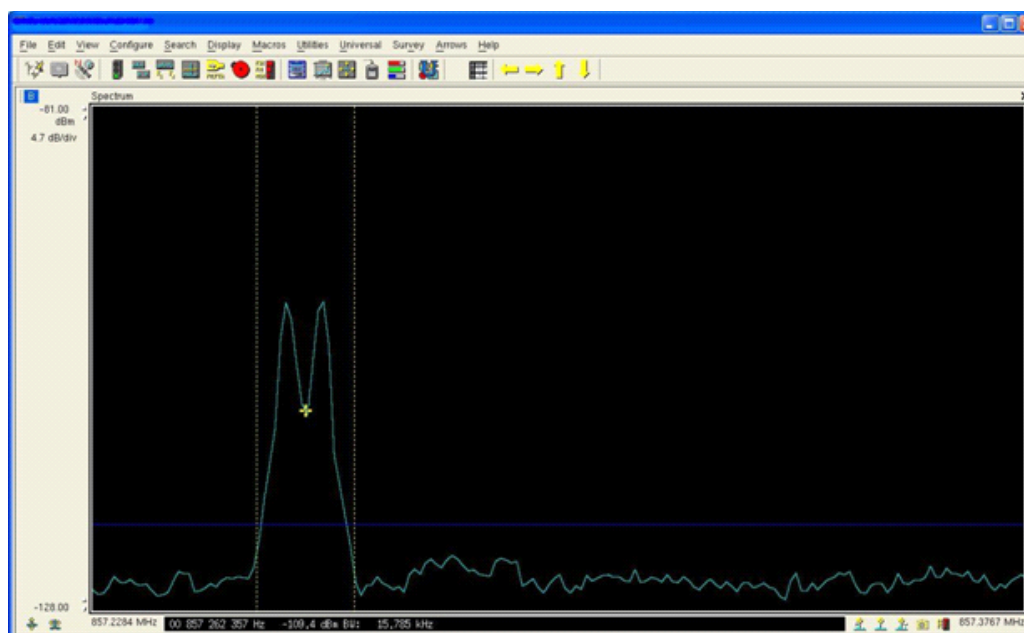
TABLE 1
Sample Frequency Allocation Table

Table of Frequency Allocations			698-941 MHz (UHF)		Page 29
International Table			United States Table		FCC Rule Part(s)
Region 1 Table (See previous page)	Region 2 Table	Region 3 Table (See previous page)	Federal Table	Non-Federal Table	
	698-806 FIXED MOBILE 5.313B 5.317A BROADCASTING		698-763	698-763 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
			763-775	763-775 FIXED MOBILE NG158 NG159	Public Safety Land Mobile (90R)
			775-793	775-793 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)
790-862 FIXED MOBILE except aeronautical mobile 5.316B 5.317A BROADCASTING			793-805	793-805 FIXED MOBILE NG158 NG159	Public Safety Land Mobile (90R)
	5.293 5.309 5.311A		805-806	805-806 FIXED MOBILE BROADCASTING NG159	Wireless Communications (27) LPTV and TV Translator (74G)

By using a spectrum analyser, vector signal analyser or monitoring receiver, or a spectrum monitoring system containing this functionality, the Monitoring Service can determine the signal centre frequency, frequency distance between adjacent carriers and signal bandwidth. The frequency should be checked against the frequency plan to make sure the signal is centred on one of the allocated channels. Also, the signal bandwidth should be checked for compliance with the standards of channelization for the frequency band of interest. Figure 1 shows how display markers can be used to determine centre frequency, signal bandwidth and power measured at the receiver input.

FIGURE 1

Sample spectral display with markers



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Table 2 provides a comprehensive set of analysis methods that may be employed by the Monitoring Service to detect signals and estimate signal external parameters. Many signal analysis software packages have the ability to perform mathematic operations on time or spectral data or a series of spectral data. Such packages can be used to make these kinds of estimations of signal external parameters.