Technical Handbook
for
Radio Monitoring

VHF/UHF

Edition 2011

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Books on Demand GmbH

Description of modulation techniques
and waveforms
with 181 pictures and
75 tables

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

Email: roland@proesch.net, k.daskalaki@gmx.de
Production and publishing: Books on Demand GmbH, Norderstedt, Germany
Cover design: Anne Prösch
Cover fotos: Mike Höhn, Roland Prösch
Printed in Germany

Webpage: technicalhandbook.frequencymanager.de

ISBN 9783842351622

Acknowledgement:

Thanks for those persons who have supported us in the preparation of this book.

Disclaimer:

The information in this book have been collected over years. The main problem is that there are not many open sources to get information about this sensitive field. Although we tried to verify these information from different sources it may be that there are mistakes. Please do not hesitate to contact us if you discover any wrong description.

Content

1. List of Pictures

2. List of Tables

3. General

The “Technical Handbook for Radio Monitoring HF” is meanwhile well known and used by many radio listeners (official or private) worldwide.

Due to the high amount of systems we decided to separate the description of signals in the VHF/UHF range from those heard on HF.

This book has been written to help the listener in identifying the different modes or waveforms which are active throughout the VHF/UHF band.

It will never be complete.

But it will give a good overview which techniques are state of the art today. It has to be mentioned that most of the pictures are a result of the decoder HOKA CODE 300-32 and PROCITEC PROCEED. For the wide band spectra we have used an AOR5000 with SDR-14 or PERSEUS on the IF-frequency of 10.7 MHz.

This book is divided in four main parts:

- Basic information about modulation
- Waveforms used on VHF/UHF
- Tables for Radio Monitoirng
- Abbreviations and Index

The part basic information is giving an overview about common modulation techniques with a short description and how they look like in the spectrum or phase plane display. This part also describes standard expressions from the field of coding, error correction and so on which are often used in the field of radio communication.

The following section describes most of the waveforms which can be heard on VHF and UHF.

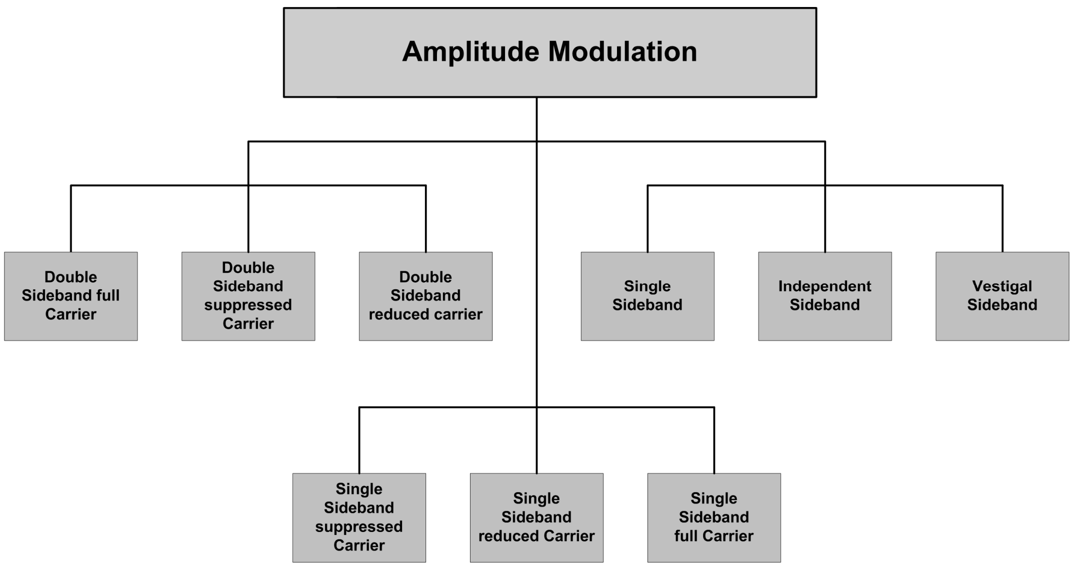
The book is finished with some helpful tables taken from th HF edition, the abbreviation table and index.

4. Description of Waveforms

Analogue Waveforms

Analogue waveforms are mainly seperated in to different forms: the amplitude modulation in which the carrier frequency is fixed and the amplitude of the signal is modulated related to the information being sent.
The other modulation form is the frequency modulation in which the frequency is changed related to the information being sent. The carrier envelope remains on the same level.

Amplitude Modulation (AM)



Picture 1: Different AM waveforms

The Ampitude modulation is mainly used for broadcast transmissions or in aeronautic mobile service on VHF. In a AM the strength of the carrier is varried in relation to the information which shall be send. In a pure AM both sidebands are modulated.

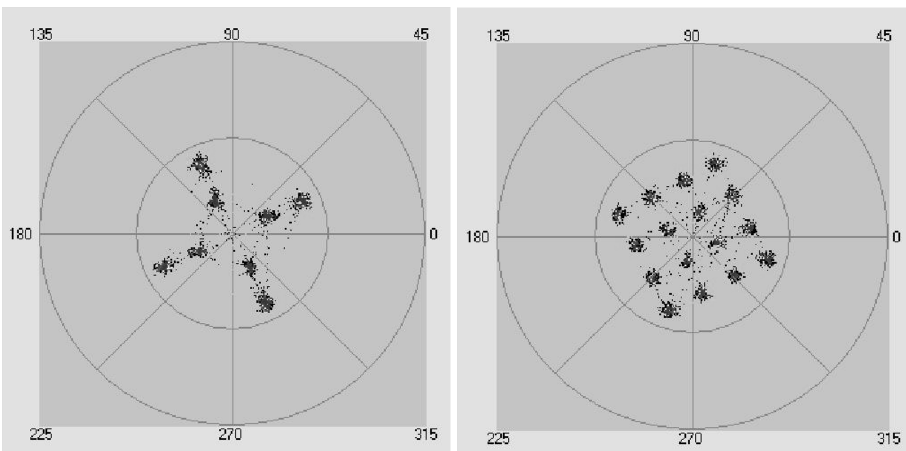
The following pictures shows the spectrum and sonagram of a typical amplitude modulation with bioth sidebands and the carrier:

Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation (QAM) is a modulation scheme in which two techniques are combined: amplitude modulation and phase shift keying (PSK). A combination of two amplitude levels and a QPSK would result in an 8QAM with 8 states representing 8 different bit sequences as shown in the following table:

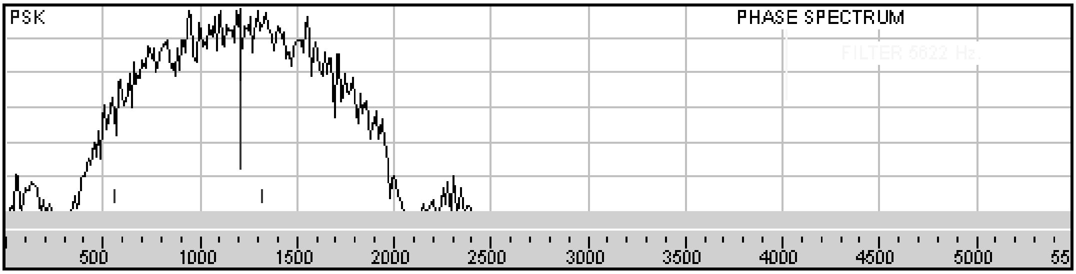
Bit Sequence	Amplitude Level	Phase Shift
000	1	0°
001	2	0°
010	1	90°
011	2	90°
100	1	180°
101	2	180°
110	1	270°
111	2	270°

Table 5: Bit values for QAM

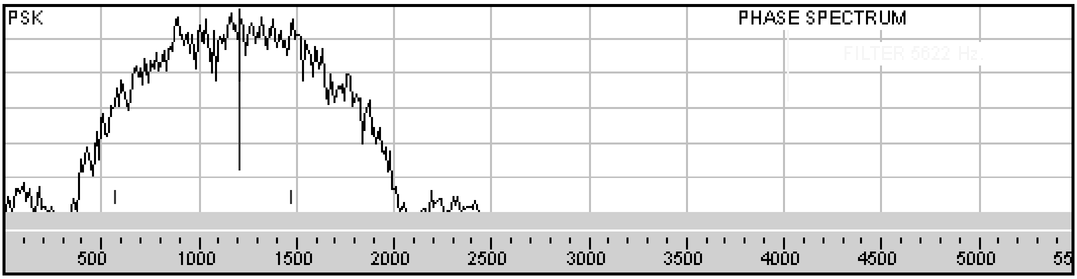


Picture 35: Example of an 8QAM and 16QAM in the Phase Plane

The next two pictures are showing the spectrum of a QAM8 and QAM16 with 600 Bd:



Picture 36: Spectrum of a QAM8 with 600 Bd



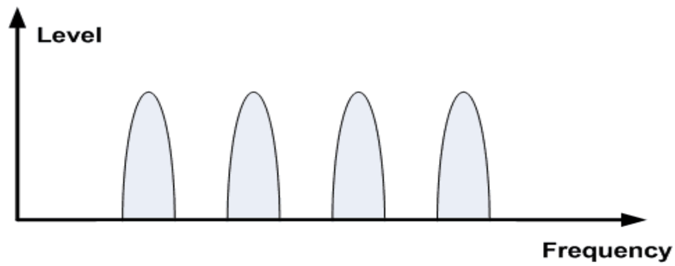
Picture 37: Spectrum of a QAM16 with 600 Bd

The main differences which can be seen in this spectrum are lower side lobes with a QAM16 compared to a QAM8.

Channel access methods

Frequency-division multiple access (FDMA)

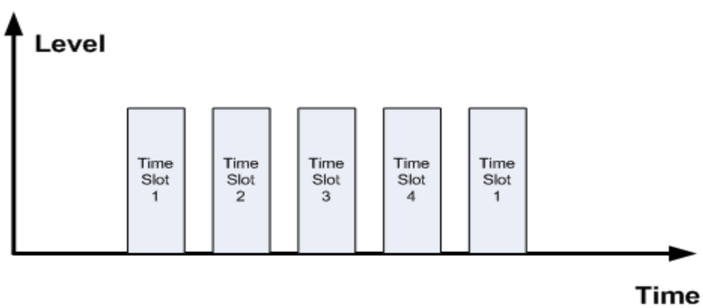
FDMA, or frequency-division multiple access, is the oldest and most important of the three main ways for multiple radio transmitters to share the radio spectrum. The other two methods are Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA).
In FDMA, each transmitter is assigned a distinct frequency channel so that receivers can discriminate among them by tuning to the desired channel.
TDMA and CDMA are always used in combination with FDMA, i.e., a given frequency channel may be used for either TDMA or CDMA independently of signals on other frequency channels.



Picture 47: Principle of FDMA

Time division multiple access (TDMA)

Time Division Multiple Access (TDMA) is a technology for shared medium (usually radio) networks. It allows several users to share the same frequency by dividing it into different time slots.
The users transmit in rapid succession, one after the other, each using their own timeslot. This allows multiple users to share the same transmission medium (e.g. radio frequency) whilst using only the part of its bandwidth they require. TDMA is used extensively in satellite systems, local area networks, physical security systems, and combat-net radio systems.



Picture 48: Principle of TDMA

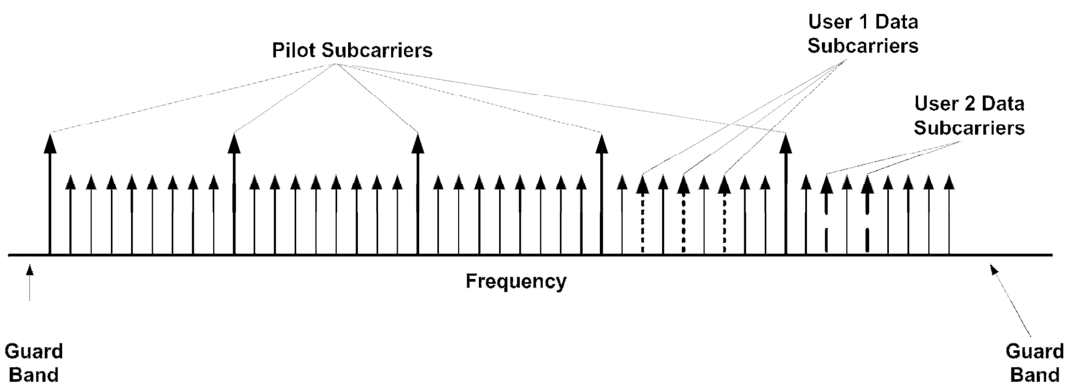
Code division multiple access (CDMA)

Generically (as a multiplexing scheme), code division multiple access (CDMA) is any use of any form of spread spectrum by multiple transmitters to send to the same receiver on the same frequency channel at the same time without harmful interference.
One important application of CDMA is the Global Positioning System, GPS.

CDMA's main advantage over TDMA and FDMA is that the number of available CDMA codes is essentially infinite. This makes CDMA ideally suited to large numbers of transmitters each generating a relatively small amount of traffic at irregular intervals, as it avoids the overhead of continually allocating and de-allocating a limited number of orthogonal time slots or frequency channels to individual transmitters. CDMA transmitters simply send when they have something to say, and go off the air when nothing is to transmit.

Orthogonal Frequency multiple access (OFDMA)

Orthogonal Frequency Division Multiple Access (OFDMA) is a multi-user version of the OFDM digital modulation scheme. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users as shown in the picture below. This allows simultaneous low data rate transmission from several users. OFDMA can also be described as a combination of frequency domain and time domain multiple access, where the resources are partitioned in the time-frequency space, and slots are assigned along the OFDM symbol index as well as OFDM sub-carrier index.

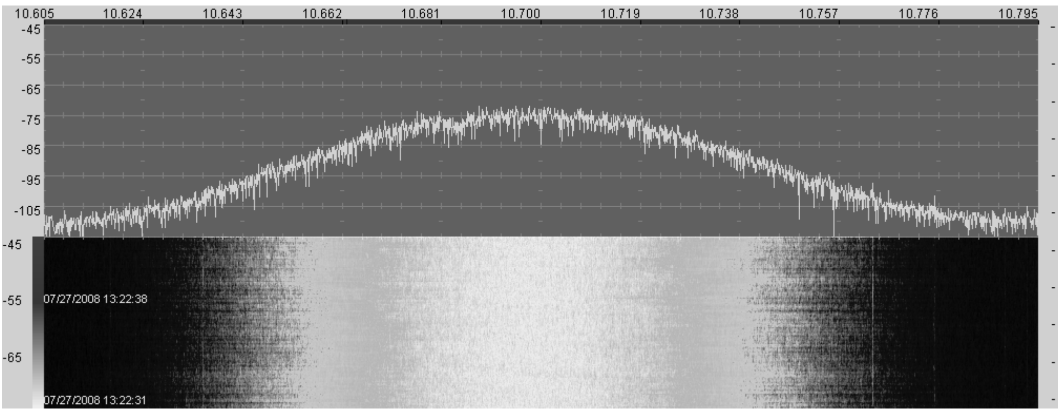


Picture 49: Principle of OFDMA

Broadcast WFM

In the broadcast service, mainly the frequency range from 87.5 MHz to 108 MHz, broadcast transmitter are modulated with a Wide Frequency Modulation WFM. The modulation index is much higher than one. This modulation from has been invented to provide high-fedelity sound over broadcast radios.

The following picture shows a typical WFM:



Picture 71: Spectrum of a WFM

The simplest signal is a FM mono transmission with a bandwidth of 15 kHz. In the late 1950's stereo and sub carriers were added to the WFM broadcast.

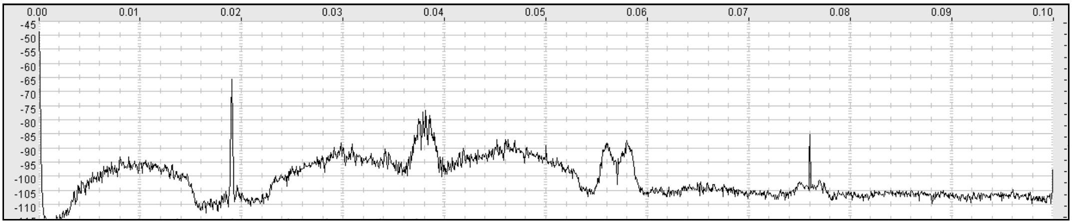
It was important that FM stereo is compatible with FM mono. Therefore the left and right channel were encoded into the sum (left + right, L+R) and the difference (left – right, L-R) between both channels. The mono receiver will use the sum of both signals to listen to both in a single loudspeaker. A stereo receiver will add the L+R and L-R signals to get the left channel and subtract L+R and L-R to get the right channel.

The (L+R) main channel signal is transmitted as baseband audio in the range of 30 Hz to 15 kHz. The (L−R) sub-channel signal is modulated onto a 38 kHz double-sideband suppressed carrier (DSBSC) signal occupying the baseband range of 23 to 53 kHz.

A 19 kHz pilot tone, at exactly half the 38 kHz sub-carrier frequency and with a precisely defined phase relationship to it, is also generated. This is transmitted at 8–10% of overall modulation level and used by the receiver to regenerate the 38 kHz sub-carrier with the correct phase.

The final multiplex signal from the stereo generator contains the main Channel (L+R), the pilot tone, and the sub-channel (L−R). This composite signal, along with any other sub-carriers (SCA), modulates the WFM transmitter.

Converting the multiplex signal back into left and right audio signals is performed by a stereo decoder, which is built into stereo receivers. The following picture shows these channels in the spectrum display:



Picture 72: Spectrum of FM stereo with sub-channels

On WFM signals also digital services are available. These services are modulated to a 57 kHz sub-carrier which is the third harmonic of the 19 kHz stereo pilot tone. This digital service is called Radio Data System RDS. This system works with a data rate of 1187.5 Bps.

Pre-emphasis and de-emphasis

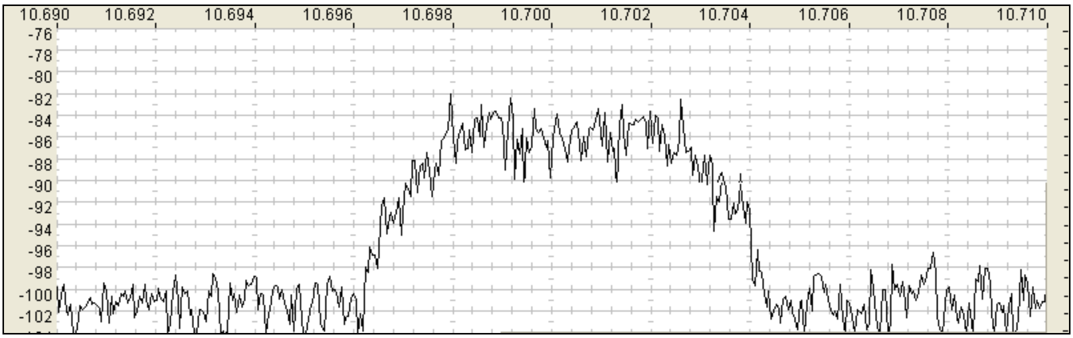
Random noise has a triangular distribution in the spectrum of a FM system. This results in the effect that noise occurs in the higher frequencies of the baseband. To work against this effect a process has been developed: pre-emphasis and de-emphasis. Before transmitted the higher frequencies will be amplified by a certain amount and after reception reduced by the corresponding amount. Reducing the high frequencies will also reduce the noise of a broadcast signal.

The amount of pre-emphasis and de-emphasis is defined by the time constant of a simple RC filter circuit. In most of the world a 50 µs time constant is used, in North America it is 75 µs. This applies to both mono and stereo transmissions and to baseband audio (not to the subcarriers).

(Emergency Position Indicating Radio Beacons), as well as hand-portable versions for smaller Vessels.

INMARSAT-M

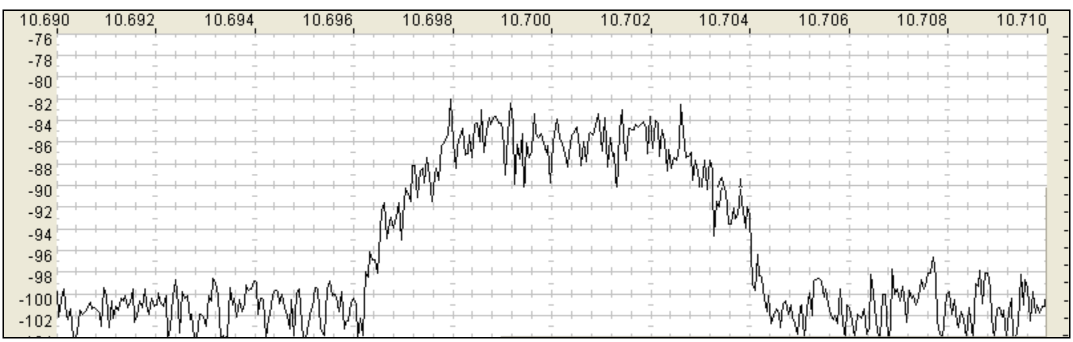
INMARSAT-M was introduced in 1993 to complement the existing INMARSAT-A system by providing global telephone/fax and data communications on an MES which is inexpensive and compact in size. The INMARSAT-M MES is smaller and lighter than an INMARSAT-A MES, making this network suitable for smaller vessels such as fishing vessels and yachts. INMARSAT-M is using 6000 Bps DPSK for the NCS or 8000 Bd OQPSK for voice. For the return channel 3000 Bps DPSK or 8000 Bps OQPSK is used.



Picture 124: Spectrum of INMARSAT M NCS

INMARSAT mini-M

The INMARSAT mini-M system was launched in January 1997 and offers the same services as INMARSAT-M, but in a smaller, more lightweight and compact unit. This MES can be made smaller because it operates only in the spot-beam coverage of the latest INMARSAT-3 satellites.
The receive modulation for voice/fax/data is OQPSK with 5.6 kbps SCPC or 6 kbps BPSK TDM. The forward channel uses a data rate of 5.6 kbps OQPSK for voice/fax/data or 3 kbps BPSK TDMA.



Picture 125: Spectrum of INMARSAT- mini-M NCS

INMARSAT Fleet F33

Fleet F33 offers an integrated data service within the spot beam, delivering a data stream at speeds up to 9.6kbit/s — although an effective throughput of up to seven times faster can be achieved using integrated compression. This service is best used for fax and sending batched transmissions, such as file transfers via e-mail.

The Mobile Packet Data Service (MPDS) provides an "always on" service where charges are made for the amount of data sent and received, rather than the time spent online.

Offering spot beam data and global voice coverage, Fleet F33 has been designed for vessels that require a smaller antenna, lighter above-deck equipment and a low-cost, simple hardware installation.

The following services are possible:

Voice 4.8 kbps
Data 9.6 kbps dedicated channel (with compression equivalent to up to 40 kbps)
Data MPDS 28.8/64 kbps MPDS (Packed data)
Fax 9.6 kbps Group 3 fax

INMARSAT Fleet F55

The Fleet F55 service allows the user to select either or both of two data services with the INMARSAT spot beams — Mobile ISDN or the Mobile Packet Data Service (MPDS). There are some fundamental differences between the two forms of communication, suiting different types of operational needs. Mobile ISDN delivers a data stream at speeds up to 64 kbps.

The Mobile Packet Data Service (MPDS) is best where network transmissions need to be of a higher frequency, are less urgent or involve smaller amounts of data. MPDS also lets you stay on line all the time, since you only pay for the amount of data sent and received rather than the time spent online — making it ideal for e-mail and web browsing.

Offering spot beam data and global voice coverage, Fleet F55 has been designed for vessels that require a smaller antenna, lighter above-deck equipment and a low-cost, simple hardware installation.

The following services are possible:

Voice 4,8 kbps, 64 kbps, 3.1 kHz audio
Data 64 kbps MPDS (Packed data)
56/ 64 kbps ISDN
Fax 9.6 kbps Group 3 fax, 64 kbps Group 4 fax, 3.1 kHz audio

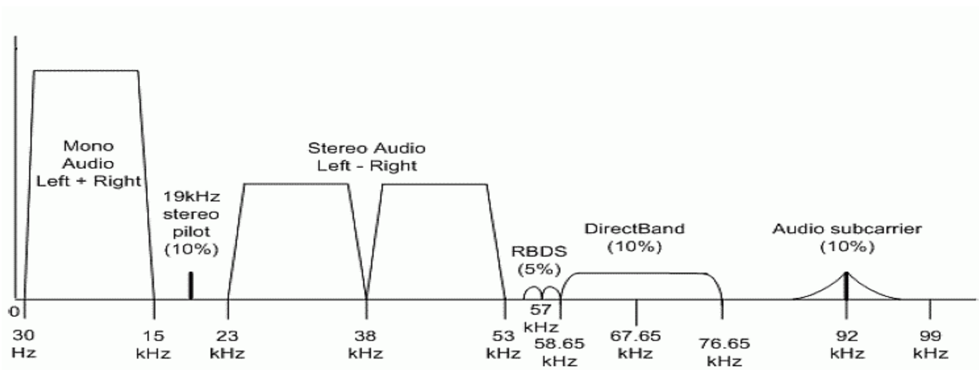
RDS/RBDS

Radio Data System, Radio Broadcast Data System

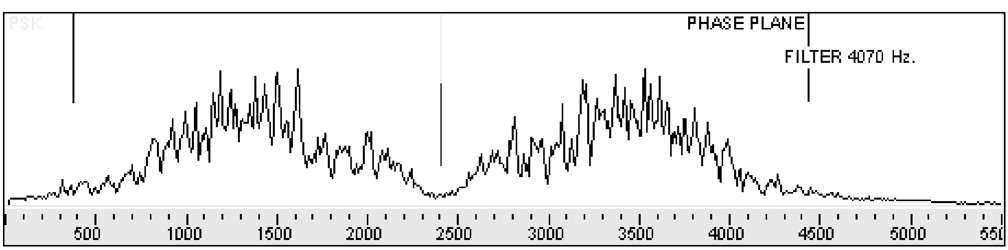
Radio Data System (RDS) is a communications protocol standard from the European Broadcasting Union (EBU) for sending digital information using conventional FM radio broadcasts. The RDS system standardises several types of information transmitted, including time, track/artist info and station identification. RDS is a standard in Europe and Latin America since the early 1990s.

Radio Broadcast Data System (RDBS) is the official name used for the U.S. version of RDS. The two standards are nearly identical. Slight differences are mainly which numbers are assigned to each of the 31 musical and other program formats the RBDS system can identify. RBDS was approved by the NRSC.

RDS and RDBS use a 57kHz subcarrier to carry data at 1187.5 bits per second. The 57 kHz was chosen for being the third harmonic of the pilot tone for FM stereo. This will not cause interference or intermodulation with the pilot tone or with the stereo difference signal at 38 kHz. The data format allows forward error correction (FEC).



Picture 165: Spectrum of FM broadcast carrier

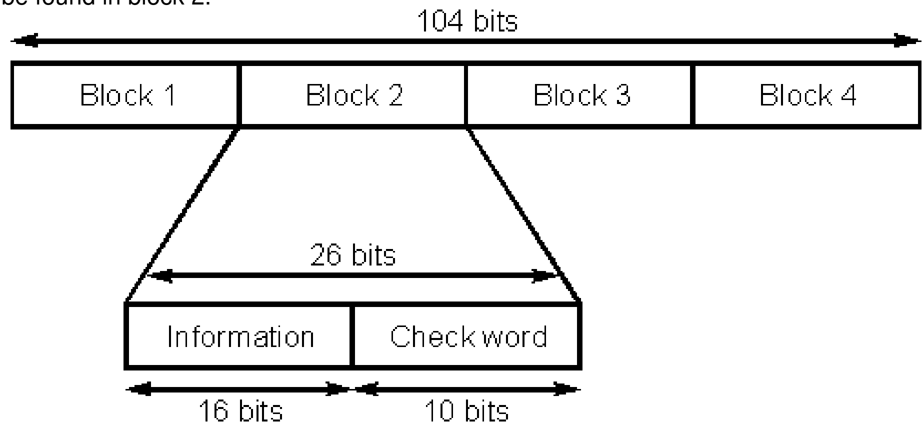


Picture 166: Spectrum of a RDS signal within a WFM signal

RDS is modulated on the subcarrier with a QPSK waveform with a data rate of 1187.5 Bps. This is equal to the frequency of the RDS subcarrier divided by 48.

Data is transmitted in groups consisting of four blocks. Each block contains a 16 bit information word and a 10 bit check word as shown in the next picture. This means that with the data rate of 1187.5 bit per second approximately 11.4 groups can be transmitted each second.

The data groups are structured so that data can be transmitted as efficiently as possible. Different stations will want to transmit different types of data at different times. To cater for this there are a 16 different group structures.
Mixing of different types of data within groups is kept to a minimum. However the coding structure is such that messages which need repeating most frequently normally occupy the same position within groups. For example the first block in a group always contains the PI code and PTY and TP are to be found in block 2.



Picture 167: RDS data structure

RDS data structure

In order that a radio knows how to decode the data correctly, each type of group has to be identified. This function is performed by a four bit code occupying the first four bits in the second block.
Once generated the data is coded onto the subcarrier in a differential format. This allows the data to be decoded correctly whether the signal is inverted or not. When the input data level is "0" the output remains unchanged but when a "1" appears at the input the output changes its state.
With the basic signal generated the spectrum has to be carefully limited. This has to be done to avoid any cross talk in phase locked loop decoders. The power density close to 57 kHz is limited by the encoding each bit as a biphase signal. In addition to this the coded data is passed through a low pass filter.

The following information fields are normally contained in the RDS data:

Alternative Frequencies (AF)

This enables a receiver to re-tune to a different frequency providing the same station when the first signal becomes too weak. This is often utilised in car stereo systems.

Clock Time (CT)