



ROHDE & SCHWARZ

Test and Measurement
Division

Software Manual

Software for Generating COFDM Signals in Combination with ARB Waveform Generator ADS

DAB-K1

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Data Sheet

1 Software Introduction

The DAB-K1 software provides a user-friendly tool for the calculation and output of COFDM signals for Digital Audio Broadcasting (DAB) and other applications together with the programmable Dual Arbitrary Waveform Generator ADS and the Signal Generator SMHU 58. In addition, DAB-K1 allows COFDM signals to be generated with quadrature amplitude modulation (QAM), as they are used for eg Digital Video Broadcasting (DVB).

Features of the DAB-K1 software:

- Simulation of Digital Audio Broadcasting (DAB) signals with COFDM modulation
- All DAB modes 1, 2 and 3 are selectable
- Generation of null symbols (time reference symbol)
- Generation of phase reference symbols (time-frequency-phase reference symbol)
- Consideration of guard intervals of selectable length
- Repetition of individual symbols with and without guard interval
- Simulation of a DAB frame of 77 or 144 symbols, number of symbols is user-selectable
- Simulation of other COFDM signals, eg with QAM for DVB (Digital Video Broadcasting)
- Calculation of other multi-carrier signals with a user-selectable number of carriers (up to 8190 carriers) and selectable frequency spacing of the carriers
- Calculation of signals with random modulation or with user-selectable phase and amplitude modulation of the individual carriers
- Simulation of signal distortions such as amplitude and phase distortion
- Simulation of fading distortions
- Calculation of time signals from the amplitude and phase values of the individual carriers
- Save and recall of calculated symbols and sequences
- Fast data transfer to the ADS via IEC/IEEE bus
- Conversion of the COFDM-modulated signals into the frequency range of the SMHU 58 (5 MHz to 1950 MHz)
- Bandwidth of the modulated signals 1.5 MHz for DAB modes and up to 32 MHz for user-defined COFDM signals
- Frequency spacing of the COFDM carriers in line with DAB modes or freely selectable from 1 Hz to 10 MHz

2 Preparations for Use

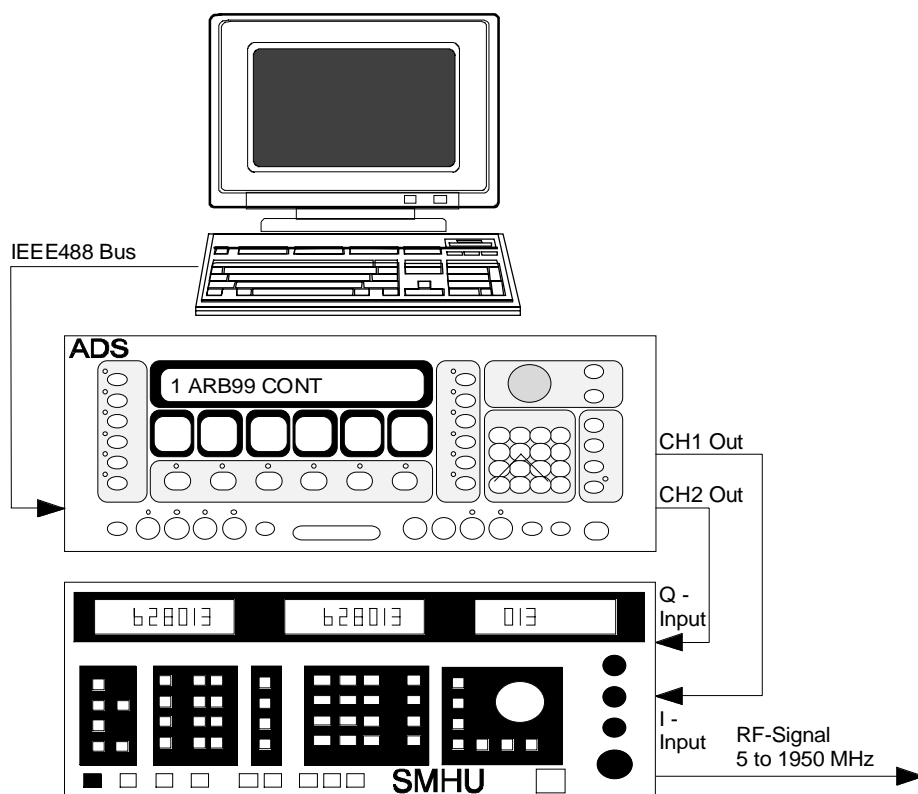
2.1 Hardware Requirements

The computer hardware used must meet the following requirements:

The program can be run on any IBM-AT compatible computer (80286, 80386, 80486) with 640-kByte RAM. For reasons of speed, we recommend you to use a computer with a clock rate of not less than 25 MHz. A co-processor (80287, 80387) is supported, increasing the computing speed.

The calculated signals are transferred to the Arbitrary Waveform Generator ADS via the IEC/IEEE bus. The program supports the IEC/IEEE bus interface cards PAT-K1 from Rohde & Schwarz and the National Instruments cards PCIIA to standard IEEE 488.1 and 488.2. For this purpose, the IEC-bus drivers of the software Rohde & Schwarz PS-K2 or the National Instruments driver GPIB.COM must be loaded (incorporation with DEVICE=GPIB:COM in the file CONFIG.SYS).

The output signals from the ADS are applied as modulation signals to the I and Q modulator inputs of Signal Generator SMHU 58 and converted into the frequency range of the generator 5 MHz to 1950 MHz. SMHU 58 is not IEC-bus controlled.



02.12 Installation of the DAB-K1 Software

DAB-K1 is used in conjunction with an IEC/IEEE bus conforming to the standards IEEE 488.1/488.2 and the Arbitrary Waveform Generator ADS from Rohde & Schwarz (memory capacity 16 or 64k words). If no bus or ADS is currently connected, the program enables you to calculate and store symbols and sequences. They can be transferred to the ADS at a later date.

There are three files on the program diskette: INSTALL.EXE and DAB____.EX_ and README.TXT.

The file README.TXT contains information about the program which was not available at the time this handbook went to press. It can be read with any word-processing program.

The program is installed with the help of the INSTALL.EXE file. Change to your disk drive and select INSTALL on the program diskette.

The installation program recognizes the hardware configuration and prompts the user for the destination drive and the destination directory DAB-K1 is to be installed on (default setting C:\DAB).

The DAB____.EX_ file is copied on the destination directory you have entered. The DAB____.EX_ file is a compressed file capable of unpacking itself. In doing so, the subdirectory \DATA is created and all example files are copied to this directory.

To start the DAB-K1 software, change to the selected destination directory (default setting when the installation program has ended) and enter DAB.BAT. The program assumes the address 14 to be the IEC-bus address of the ADS. Should your ADS not be set to this address, you can specify the address when starting the program. Example: DAB 5<Enter> starts the program if the ADS is set to address 5.

3 Menu Operation and Window Structure

DAB-K1 can be operated via mouse and keyboard. With the cursor keys or by entering the highlighted letters, the menus are selected. The individual menu items are activated using the ENTER key. Abortion is caused by ESC. A peculiarity occurs when activating a pulldown menu of the second level. Pressing the cursor keys right/left in this menu does not change the menu structure. Use the ESC key to enter the next higher menu level.

For mouse operation, select a menu item by positioning the mouse cursor on the menu item and click using the left mouse button. Change the menu simply by clicking on another menu item.

Alternate use of keyboard and mouse is possible.

3.1 Window Structure, Meaning of the Entries in the Display Field

Windows are made up of the menu line with pulldown menus folding down, status line with context-sensitive comment line and the display field with the specific parameters for the currently active settings and data.

3.1.1 Pulldown Menus

The pulldown menus are provided in the uppermost screen line. Select them by entering the highlighted letter or using the cursor keys and the ENTER key or by clicking with the mouse. The individual menu items are selected analogously. Menu items which currently cannot be executed (eg "Save Symbol" when no symbol has been calculated yet) are displayed in grey without highlighted letter.

3.1.2 Display Field

The first column in the display field refers to the generator and the parameters of memory capacity, IEEE address of ADS, clock rate and symbol length. The middle column reads out the substantial parameters of the test signal to be generated. In the last column, the current data source of symbol and sequence is visible, which is the file name (eg "SYM01.SYM", "MODE1.SEQ") for loaded or calculated and saved files. In the case of data just calculated but not yet saved, the text "not saved" is displayed.

3.1.3 Status Line with Help Text

The status line in the lowermost screen line provides a help text to any menu item. While relatively time-consuming actions are being executed (eg calculation of a symbol) an appropriate hint is output in the status line.

3.2 The Load Window

Selection of the menu items "Load Data File", "Load Symbol" or "Load Sequence" opens the Load window. It contains the already available files with the associated file name extension (*.SYM, *.USR, *.SEQ, *.DAT), facilitating the selection of a file. The mouse or keyboard can be used for selection. Abortion is possible using ESC. The name of your choice must **always** be acknowledged by ENTER, even after selection with the mouse (double click is not accepted). After build-up of the Load window, all files with the file name extension provided for the current path are displayed. The specification of the path and file name extension can be changed, or a completely new file name can be entered. To this end, change to the input line stating the path and standard extension using the TAB key or the mouse. With the cursor keys, INSERT, DELETE and Backspace, the input line can be edited. Specification of the path in the input line can be omitted when

the directory is not to be changed. Only when you enter a completely new and valid path, the new directory is switched to.

Default setting is the working directory \DATA with the following file name extensions:

Configuration files	*.CFG
Phase reference files:	*.DAT
Sequence files:	*.SEQ
Symbol files:	*.SYM
User files:	*.USR

3.3 The Save Window

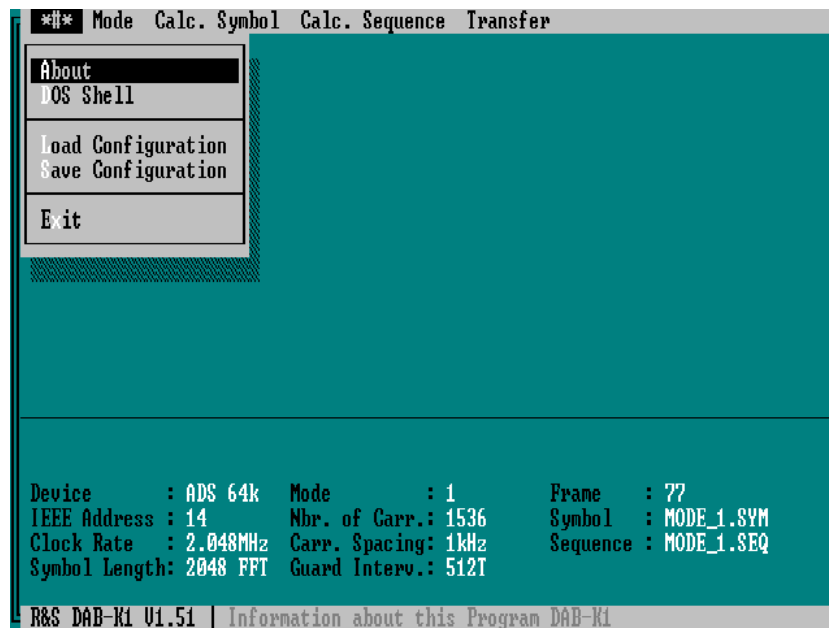
The Save window has the same structure and can be operated in the same way as the Load window. The only difference is that entry is started in the input line. Before overwriting an already existing file the program asks whether you are sure.

4 Functions of the DAB-K1 Software

This section gives detailed information on the function of all menu items.

04.1 Menu

This menu provides information on the program and permits calling of the operating system level, loading and saving of program settings and terminating of the program.



04.1.1 About

This menu item provides information on the version number and the release date of the Software DAB-K1 used. If you have questions as to the program, also indicate the information given here.

04.1.2 DOS Shell

This menu item permits calling of the operating system level (DOS level). You can use this menu to start other programs in the meantime without changing the program settings. You can, for example, execute the program RUNINSWP.EXE supplied (see section "Files Supplied"). To leave the operating system level, enter the command EXIT<Enter> and you will return to the program DAB-K1.

04.1.3 Load Configuration

This menu item permits to load a previously saved program setting. All settings are loaded, ie DAB mode, number of carriers, carrier spacing, amplitude levels, phase steps, guard interval, symbol length, number of symbols per frame, number of symbols per sequence, time ref. symbol, phase ref. symbol, amplitude distortion, phase distortion, fading ranges, clipping power, clock rate, ARB number, sequence number and D/A converter resolution. The settings are loaded from an ASCII file with the extension .CFG.

04.1.4 Save Configuration

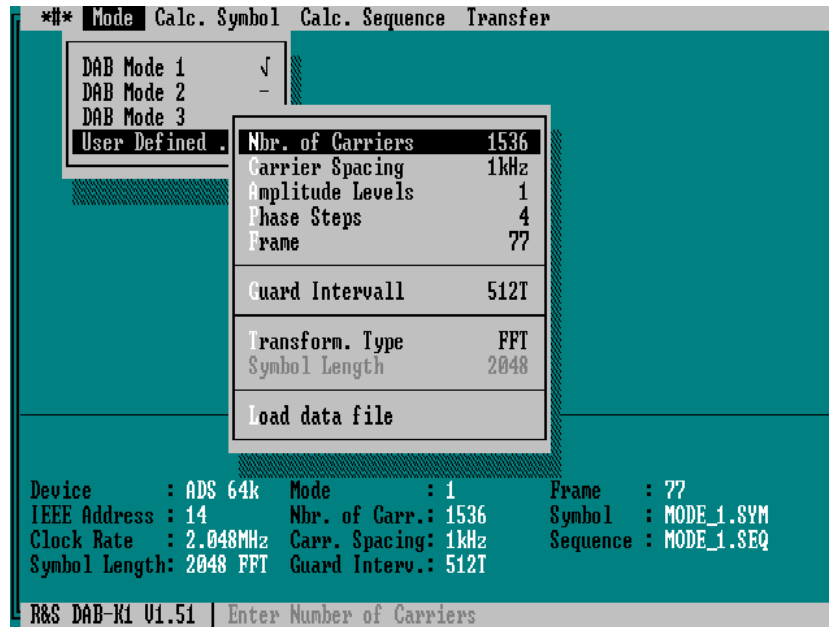
This menu item permits to save a program setting stored before. All settings are stored, i.e. DAB mode, number of carriers, carrier spacing, amplitude levels, phase steps, guard interval, symbol length, number of symbols per frame, number of symbols per sequence, time ref. symbol, phase ref. symbol, amplitude distortion, phase distortion, fading ranges, clipping power, clock rate, ARB number, sequence number and D/A converter resolution. The settings are saved in an ASCII file with the extension .CFG.

04.1.5 Exit

The menu item Exit allows to terminate the program DAB-K1. If you want to make further use of settings or calculated data, you have to save them before terminating the program.

4.2 Mode

This menu item permits you to select the various DAB modes as well as a specific "User defined" mode for predefining the calculation.



4.2.1 DAB Modes 1 to 3

These menu items allow the selection of the various DAB modes 1, 2 or 3, which differ in the number of carriers and symbol time. The values preset here correspond to a preliminary DAB specification (see also Table in Annex). All values can be varied when switching to the "User defined" menu after having selected a DAB mode. Also, the length of the guard interval can be changed in this manner. The guard interval is, however, taken into account only when the symbols are transferred to the ADS.

4.2.2 User Defined

The menu item "User defined" permits you to create specific signals with any number of carriers (max. 8190), carrier spacings, amplitude levels, phase steps, number of symbols per frame you desire. The guard interval can also be set. The values of a previously selected DAB mode serve as default values for the individual settings. These default values can then be changed as you desire.

Caution: A change in the length of the guard interval made under this menu item is also considered in the data transfer to the ADS for the DAB modes 1, 2 and 3. However, it is not saved together with the symbol to the hard disk. Before transferring signals to the ADS, check the setting of the guard interval and, if required, modify it in this menu.

When the DAB Specification has been drawn up completely, this menu item can be used for the generation of signals exactly complying with the specification.

4.2.2.1 Nbr. of Carriers (Number of Carriers)

With this menu item, you can set the desired number of carriers in "User defined" mode. The values must lie in the range of 2 to 8190 as a minimum of 4 values is required for the calculations. More than 8190 carriers exceed the limits of the data fields used in the program.

4.2.2.2 Carrier Spacing

This menu item enables you to enter the frequency spacing of the carriers to be generated. The clock rate of ADS is calculated from this number and the symbol length (see also Annex "Relationship between Number of Carriers and Required Memory Capacity").

4.2.2.3 Amplitude Levels

This menu item permits you to enter a number of different amplitude levels of the carrier which are to be considered in the calculation of symbol. In the case of DAB signals, all carriers have the same amplitude, which means that the number of amplitude levels is 1. With numbers higher than 1, multi-stage modulation of the individual carriers can be simulated as is used for example in QAM (Quadrature-Amplitude Modulation) or DVB (Digital Video Broadcasting).

4.2.2.4 Phase Steps

This menu item allows the number of phase steps used in the modulation to be entered. For DAB signals, the number is 4, ie the carriers are modulated by 0° , 90° , 180° or 270° .

4.2.2.5 Frame

The number entered here defines the number of symbols combined to form a frame in the calculation of a sequence. A frame consists of a null symbol, a phase reference symbol and a random sequence of n different symbols where n can be defined in the "Calc. Sequence" menu as "Nbr. of Symbols". The various symbols are repeated in random sequence until the frame length is obtained. Subsequently, the entire frame is repeated.

4.2.2.6 Guard Interval

The length of the guard interval is entered here. "0" means no guard interval, the maximum value is given by the symbol length minus one. The length of the guard interval is considered in the transfer of the symbols to the ADS.

04.12.52.17 Transformation Type

For calculation of the DAB symbols, a Fast Fourier Transformation (FFT) is normally used. This type of calculation offers the highest computing speed. The order of the FFT depends on the number of carriers used and is the next higher power of the number 2. Example: Number of carriers 1536, this results in the symbol length and the order of the FFT of $2^{11} = 2048$. In the case of applications that require a number of carriers near one of these powers of 2, unfavourable conditions as to the symbol length or the spacing of the aliasing frequencies may be produced. In this case, a Discrete Fourier Transformation (DFT) may be selected, which permits number of carriers and symbol length to be selected separately. However, a disadvantage consists in the considerably increased duration of calculation. The following values have been determined using a computer 486 DX2-50 and are to serve as reference values for the duration of calculations.

Order of Fourier transformation	Duration of FFT calculation	Duration of DFT calculation
128	0.11 s	2.3 s
256	0.27 s	10 s
512	0.59 s	38 s
1024	1.37 s	2 min 30 s
2048	3.08 s	10 min
4096	7.02 s	40 min
8192	14.9 s	2 h 40 min

4.2.2.8 Load Data File

The menu item "Load data file" permits the loading of a file including any desired settings for the number of carriers as well as for the amplitude and phase values of the individual carriers. A user-defined file specifying amplitude and phase values can be loaded. Another possibility is defining the rectangular coordinates or the real and imaginary parts instead of the amplitude and phase values (see Section "User File Structure").

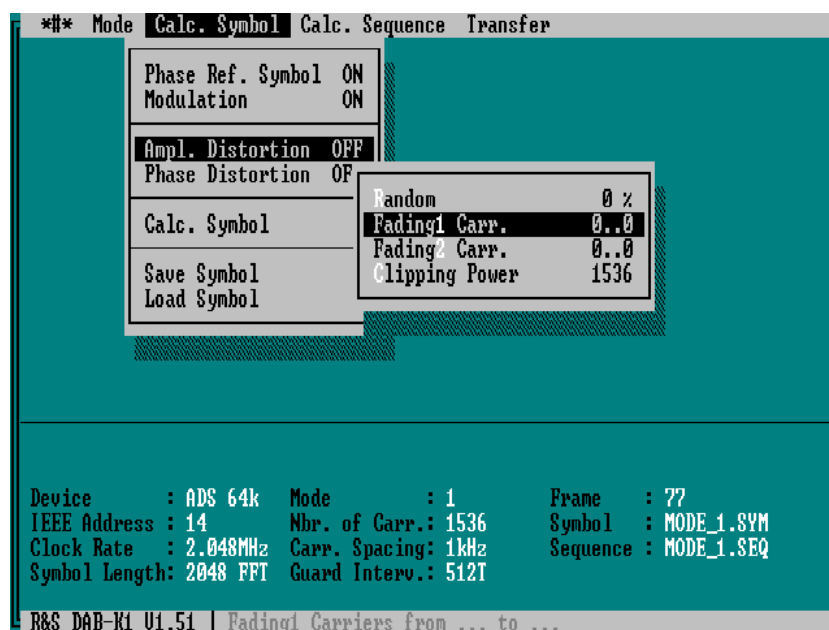
Implementation of any desired modulation specifications, such as 64QAM, fading of individual carriers or specific phase relations is possible using this menu item. Please note that, in any case, a symbol calculation must be carried out after having loaded the parameters. To this end, call the menu item "Calc. Symbol".

The values loaded from the data file are saved in a data field, which, however, changes its contents during calculation of a symbol. If a new calculation is to be performed with the data, the data file must be loaded again. An error message with the contents "Load User Data again" prompts the user to do so.

Note: The modulation in the menu Calc. Symbol is automatically switched to OFF.

4.3 Calc. Symbol

The settings required for the calculation of the time characteristic of a symbol can be made here.



4.3.1 Phase Ref. Symbol (Time-Frequency-Phase Reference Symbol, Phase Reference Symbol)

With the menu item "Phase Ref. Symbol" switched to ON (default setting after program start), the phase relations between the carrier phases included in a reference file are used as basis for the calculation of the phase modulation. The program loads these carrier phases automatically from a file, the name of which includes the value for the number of carriers (eg mode 1 with 1536 carriers results in the file name => "RUNI1536.DAT"). When this file cannot be found, the attempt to calculate a symbol with reference symbol is aborted. The calculation is possible only after the option Phase Reference Symbol has been switched off (see also "Structure of the Phase Reference File" and the example file in the Annex). The reference symbol must be transferred into the ARB numbers 04 to 07 of the ADS in order to allow for its proper consideration in the calculation of a sequence.

Note: The files supplied include a program RUNINSWP.EXE. Using this program, phase reference files RUNI*.DAT can be generated for any number of carriers. The phase relations of the carriers are set such that the resulting peak power of the calculated symbol is as low as possible.

4.3.2 Modulation

With the menu item "Modulation" ON (default setting after program start), the carrier phase relations are provided with a random modulation. It is carried out with - in addition to the reference phases specified in the respective RUNI*.DAT file - 0°, 90°, 180° and 270° in the DAB modes 1, 2 and 3 or, in the "User defined" mode, with 360° divided by the number of phase steps.

Note: If a data file with user data is loaded in the menu User defined, the modulation is switched off automatically (Modulation OFF). This serves to make sure that the amplitudes and phase relations of the carriers defined in the data file are considered in the calculation of the symbol without additional modulation.

4.3.3 Ampl. Distortion (Amplitude Distortion)

The program permits the generation of random amplitude distortions. A distinction is made between random variations of the carrier amplitudes and the complete carrier fading in two frequency ranges.

04.13.53.1 Random

The menu item "Random" allows you to enter a maximum value in percent of the carrier amplitude for an amplitude distortion similar to noise. Each carrier amplitude then shows random distortion between 0 and this maximum value. Amplitude distortion is switched OFF again by entering "0" as value.

04.13.53.2 Fading Carr.

For simulation of fading distortions, the carriers can be faded in two frequency ranges Fading1 and Fading2. Enter the start and stop value of each carrier to be faded. In the range between start and stop value, each carrier is overwritten by the amplitude value zero. Fading is switched off again by entering "0" as start and stop value.

04.13.53.3 Clipping Power

COFDM signals may feature a very high peak power. This is produced if, even for a short moment, the phase relations of the carriers are such that their voltage is added. The resulting peak power may be a multiple of the thermal power expected after multiplication of the number of carriers by the power of an individual carrier. DAB signals typically feature a peak power that is 8 to 15 times higher than the sum of the carrier powers. All elements in the transmission path of the COFDM signals, in particular amplifiers, must be able to transfer this peak power.

Limiting effects produced for example by insufficient dynamic range of amplifiers, or wanted limitation of the peak power of the signal can be set by defining the clipping power. The value range of the clipping power extends from 1 to the maximum number of the carriers. If this limitation is to be avoided, the value of the clipping power is to be set to the number of carriers.

The actual peak power of the signal can be obtained after calculation from the file MAXPOWER.TXT.

4.3.4 Phase Distortion

This program, too, enables the simulation of random phase distortion in order to test, for example, the sensitivity of decoders. The menu item "Phase distortion" allows a value for the maximum phase distortion to be entered in degrees. Each carrier phase then shows random distortion between 0 and this maximum value. Phase distortion is switched OFF again by entering "0" as value.

4.3.5 Calc. Symbol

This menu item starts the calculation of a symbol. The calculation takes the parameters set for a signal with or without amplitude and/or phase distortion into account. For carrier modulation, a random sequence modulating the phase relations of all carriers is used. The modulation is performed with - in addition to the reference phases specified in the respective RUNI*.DAT file - 0°, 90°, 180° and 270° in the DAB modes 1, 2 and 3 or, in the "User defined" mode, with 360° divided by the number of phase steps.

In the "User defined" mode, it is also possible to define several additional amplitude levels. Signals with quadrature amplitude modulation (QAM) can thus be calculated. Hence, the setting of 8 amplitude steps and 8 phase steps results in signals with 64QAM.

The data required for the transfer are generated and split up into the respective data portions (I and Q component as well as guard portion for I and Q components). The data values thus produced are available for

transfer. There is also the possibility of saving them as ASCII files and transferring them at a later date. (file name *.SYM).

The guard component is not considered until the symbol is transferred to the ADS (see Section "Transfer Symbol"), which allows you to modify the symbol (in the "User defined" menu) after symbol calculation.

Generating time signals with an arbitrary waveform generator involves frequency-dependent, SIN(X)/X-wave amplitude distortion of the generated carriers (see also Figure in 7.9.3). This amplitude distortion is automatically accounted for in the calculation and thus removed.

When the symbol is calculated, the time distribution of the peak power referred to the average thermal power of all carriers is also determined and stored in a file MAXPOWER.TXT. The average thermal power is the sum of the power of the individual carriers.

The first line saves date and time of the calculation, the number of carriers used and the maximum peak power of the signal. If the clipping power is set to low values, the peak power is equal to the clipping power. The value P_{crest} indicates the peak value of the signal obtained without clipping. The subsequent lines indicate the distribution of the signal power in percent of the symbol power. The pair of values <6 and 0.63 in the example mean that the power of 6* is exceeded by the thermal power only in 0.63% of the time.

The file MAXPOWER.TXT is an ASCII file that can be read using any word processing program. The values of each new calculation are appended to the file. If the values are no longer required, the file can be deleted.

06-23-1994	21:44:56	Nbr.Carr.: 1536	Max.Power: 7.57														
Power Distribution (without clipping, Pcrest = 7.57):																	
Power	< 1*	< 2*	< 3*	< 4*	< 5*	< 6*	< 7*	< 8*	< 9*	< 10*	< 11*	< 12*	< 13*	< 14*	< 15*	> 15*	
%	63.48	23.10	8.35	3.13	0.98	0.63	0.20	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Section from the file MAXPOWER.TXT

4.3.6 Save Symbol

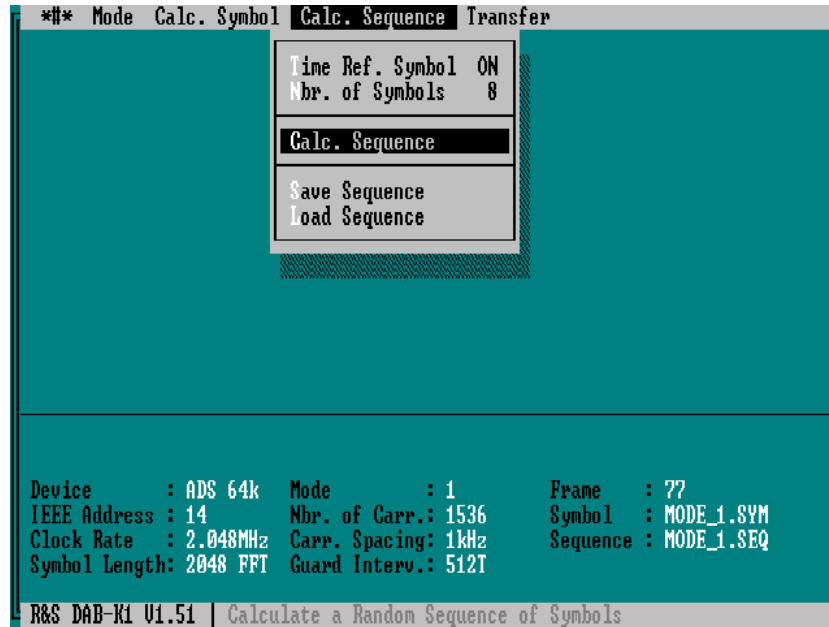
A calculated symbol can be saved using this menu item. The name may consist of up to 8 characters. The file name extension ".SYM" is automatically appended to the file name. If there is already a file with this name, you are asked whether the old file is to be overwritten. All files are saved in the \DATA directory. If you desire the file to be stored in a different directory, specify the complete path. The new directory is then changed to.

4.3.7 Load Symbol

With this menu item, a previously calculated and saved symbol can be recalled, for example, in order to transfer it to the ADS. The Load window displayed shows you which files are saved. The \DATA directory is preset provided that you have not switched to another directory before (see also Section "The Load Window").

4.4 Calc. Sequence

A random sequence of symbols is calculated, taking into account the memory capacity of the connected ADS as well as the number of symbols per frame specified in the individual modes. Activation or deactivation of "Time Ref. Symbol" (null symbol) and time frequency phase reference symbol (phase reference symbol, when ON in the "Calc. Symbol" menu) as well as the entry for the guard interval are considered.



4.4.1 Time Ref. Symbol (Null Symbol)

With the menu item "Time Ref. Symbol" switched ON (default setting after program start), the standard wave numbers for the null symbol (ARB number 00 and 01) are set to the first position in the sequence when a sequence is calculated. As any other symbol, the null symbol for the respective DAB mode must first be calculated and then transferred to the ADS. A null symbol can be calculated by defining fading for all carriers in the associated DAB mode.

4.4.2 Nbr. of Symbols (Number of Symbols)

The menu item "Nbr. of Symbols" permits the consideration of a certain number of previously calculated symbols which, together with the respective signal and guard components, must be in the ARB wave numbers 08, 12, 16. The maximum number of symbols depends on the memory capacity of the ADS (16k or 64k) and the length of the symbols (see also the note in Section "Calc. Sequence" and "Annex"). The numeric value under "Nbr. of Symbols" must consider the time reference symbol (null symbol) and the time frequency phase reference symbol, when they are activated. They being active or not also influences whether you can enter 1, 2 or 3 as minimum value for the number of symbols.

4.4.3 Calc. Sequence

This menu item is used to start the calculation of a sequence.

The time reference symbol (null symbol) and the time frequency phase reference symbol are considered only once at the beginning of a sequence, all other symbols are selected in a random sequence until the set number of symbols per frame is obtained.

During the calculation of a sequence, a distinction is made between an activated guard interval or a guard interval of the length 0 T. With the guard interval activated (guard interval unequal to 0 T), a sequence is

generated, which requires 4 ARB numbers per symbol. When the guard interval is switched off (guard interval = 0 T), 2 ARB numbers per symbol are required. The length of the guard interval is not considered (when being ≤ 0). However it is taken into account when the individual symbols are transferred to the ADS. Due to this fact, a sequence may consist of symbols with different guard components.

Structure of a sequence

for *guard intervals* $\neq 0$ the following structure applies:

Symbol:	ARB numbers:	
Null symbol	00 - 03	(reserved for null symbol)
Reference symbol	04 - 07	(reserved for phase reference symbol)
1st data symbol	08 - 11	
.....		
6th data symbol	28 - 32	(maximum for 16k ADS in mode 1)
.....		
23rd data symbol	94 - 97	

for *guard intervals* = 0 the following structure applies:

Symbol:	ARB numbers	for sequences without guard component:
Null symbol	00 - 01	(reserved for null symbol)
Reference symbol	02 - 03	(reserved for phase reference symbol)
1st data symbol	04 - 05	
.....		
6th data symbol	14 - 15	(maximum for 16k ADS in mode 1)
.....		
48th symbol	98 - 99	

Note: As to the number of ARB signals and the memory capacity they require, the following limits apply: The sum of the lengths of all signals to be output in a sequence must not exceed 16k or 64k words per channel. Up to 100 different ARB waveforms can be saved (this applies to both ADS-types 16/64k with ARB numbers 00 to 99 being available in each type). See also Annex.

The memory capacity 16k or 64k of the connected ADS is considered in the calculation of the sequence. When no ADS can be addressed via IEC/IEEE bus, the program assumes that a 16k ADS is connected.

4.4.4 Save Sequence

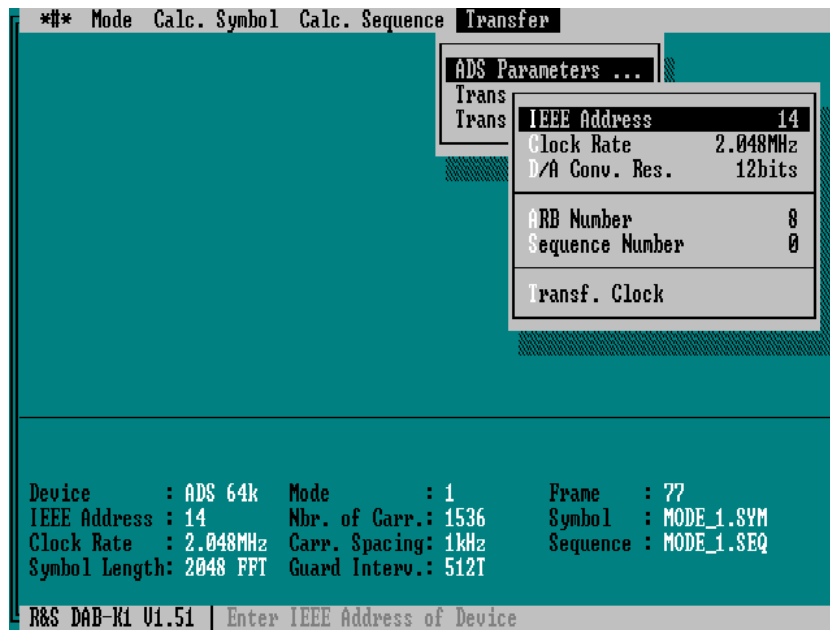
Using this menu item, you can store a calculated sequence. Its name may consist of up to 8 characters. The file name extension ".SEQ" is automatically appended to the file name. If there is already a file with this name, you are asked whether the old file is to be overwritten. All files are saved in the \DATA directory. If you desire the file to be stored in a different directory, specify the complete path. The new directory is then changed to.

4.4.5 Load Sequence

With this menu item, a previously calculated and saved sequence can be recalled, for example, in order to transfer it to the ADS. The Load window displayed shows you which files are saved. The \DATA directory is preset provided you have not switched to another directory before (see also Section "The Load Window").

4.5 Transfer

This menu item permits the setting of various ADS parameters and the transfer of calculated or loaded symbols and sequences to the ADS.



4.5.1 ADS Parameters

In this submenu, the IEC/IEEE address, clock rate as well as the number of the ARB wave or the number of the ADS sequence can be set. The clock rate is automatically transferred to the ADS when a symbol or a sequence is transferred. Menu item "Transfer Clock" allows the clock rate to be transferred at a later date. This menu item is accessible only when an ADS is connected to the IEC/IEEE bus.

04.15.51.1 IEEE Address

The IEC-bus address of the connected ADS can be changed here. The default setting is address 14. If the ADS is set to a different address, the program can as well be started with DAB <address>. Example:: DAB 5 <Enter> starts the programm DAB-K1 for an ADS set to the address 5.

04.15.51.2 Clock Rate

The clock rate of the ADS is automatically calculated from the frequency spacing of the carriers and the symbol length. For test purposes, the clock rate of the ADS can be changed. The value set here acts on the carrier spacing of the COFDM signal. The following relationship is true:

$$\text{CarrierSpacing} = \frac{\text{ClockRate}}{\text{SymbolLength}}$$

The clock rate set only becomes effective after being transferred to the ADS by calling the menu Transfer Clock.

04.15.51.3 D/A Conv. Res.

The D/A converter resolution of the ADS is 12 bits. This value determines the level spacing of the spurious signals produced outside the COFDM signal. For simulation of various effects, eg faulty D/A converters, the resolution of the D/A converter can be reduced in this menu item. The value set here is taken into account only when the signals are transferred to the ADS. It is thus possible to transfer a symbol calculated once several times with different D/A converter resolutions.

04.15.51.4 ARB Number

Before transferring symbols to the ADS, the storage locations to which they are to be transferred are to be specified. Depending on the guard interval, 2 ARB numbers (one for CH1 and CH2 each) or 4 ARB numbers (one for CH1 guard component, CH1 symbol component, CH2 guard component and CH2 symbol component each) are defined per symbol. The number specified determines the lowest ARB memory occupied. Only even numbers should be used. Valid values are all even values from 0 to 98 (96 with guard interval $\neq 0$). The default value is 8.

Caution: The previous contents of the ARB numbers is overwritten.

Example 1: Guard interval = 0, ARB number entered = 12; the ARB memory locations number 12 and 13 are occupied.

Example 2: Guard interval = 512, ARB number entered = 20; the ARB memory locations number 20, 21, 22 and 23 are occupied.

When a symbol is transferred with guard interval $\neq 0$, two sequences 98 and 99 are generated for CH1 and CH2. The time characteristic of the symbol with the guard interval is then output on the ADS. If the frequency spectrum of the symbol is to be examined, the guard interval should be switched off. To this end, the first element (guard component) in the sequences 98 and 99 can be deleted on the ADS. A still easier method, however, is to transfer the symbol again with the setting guard interval = 0 to ARB numbers that have not been used so far.

04.15.51.5 Sequence Number

Before sequences are transferred to the ADS, the number under which the sequence is to be saved must be specified. Since the sequence settings of the ADS require different ARB numbers for CH1 and CH2, two SEQ numbers are assigned in the ADS for each sequence to be transferred. If a symbol with the guard interval $\neq 0$ is transferred, two sequences 98 and 99 are used for CH1 and CH2. Thus all even numbers from 0 to 96 are valid. The default value is 0.

Example: Sequence number 12 entered; the numbers SEQ 12 and SEQ 13 are assigned on the ADS.

04.15.51.6 Transf. Clock

The value set under Clock Rate is transferred to the ADS by calling this menu item.

4.5.2 Transfer Symbol

This menu item permits the transfer of one calculated or loaded symbol to the ADS at a time. When calling the data transfer to the ADS, the currently set length of the guard interval is also taken into account. This is why the setting must be checked for any mistakes prior to the transfer. Even in the DAB modes 1, 2 and 3, the default setting of the guard interval can be changed in menu "Mode", submenu "User defined". With a guard interval length unequal to zero, the data words of each symbol are split up into signal and guard component. Subsequently, the data are transferred to the ADS where they are integrated into the ARB waves set under "ADS Parameters". The use of a guard interval requires 4 consecutive ARB numbers to save a complete symbol in the ADS (signal and guard components, each with I and Q component).

Before transferring a symbol, an appropriate ARB number must be **manually** set in the "ADS Parameters" menu, ensuring that the symbol components are correctly split up among the ARB numbers. The presetting is the first possible number for a symbol of a frame with zero and reference symbol (ARB number 08). The three subsequent ARB numbers are used automatically. The next possible ARB number would then be 12 again, that is to say always steps of 4 (8 for Sym01, 12 for Sym02, 16 for Sym03, ...). This procedure is prescribed by the automatic generation of sequences and is illustrated by the structure of a sequence (see also Section "Structure of a Sequence File"). This menu item is accessible only when an ADS is connected to the IEC/IEEE bus.

If a guard interval $\neq 0$ is set, a sequence outputting the symbol with guard interval from the ADS is automatically formed. For this purpose, the sequence numbers 98 and 99 are used for the CH1 and CH2 of the ADS, respectively.

4.5.3 Transfer Sequence

This menu item starts the transfer of a calculated or loaded sequence to the ADS. The number of the sequence into which the data are transferred is set in the "ADS Parameters" menu. Menu item "Transfer Sequence" is accessible only when an ADS is connected to the IEC bus.

Output of the signals of the sequence by the ADS is started immediately after the sequence is transferred. Please note that you obtain the desired signal only after you have transferred all required symbols to the associated ARB wave numbers.

See also section "Sequence Number".

5 File Structure

All files can be saved as ASCII files and can thus be edited using any desired text editor. Use of the software is only significant for creating a user file. The other files are generated automatically and required for save and recall of desired symbol and sequence data.

05.1 Structure of the Configuration File

All settings of the program are saved in a configuration file with the extension .CFG. A configuration file contains the following entries:

- DAB mode
- Number of carriers
- Carrier spacing
- Amplitude levels
- Phase steps
- Guard interval
- Symbol length
- Number of symbols per frame
- Number of symbols per sequence
- Use of a time ref. symbol
- Use of a phase ref. symbol
- Amplitude distortion
- Phase distortion
- Fading ranges
- Clipping power
- Clock rate
- ARB number
- Sequence number
- D/A converter resolution

The best way to produce a configuration file is to save a program setting in the menu item Save Configuration.

The configuration file can be processed using any ASCII word processing program. When saving, note that only unformatted text is saved.

5.2 Structure of the Phase Reference File RUNI*.DAT

Phase reference files RUNI*.DAT for the 3 DAB modes compiled beforehand are provided in the \DATA directory (RUNI1536.DAT for mode 1, RUNI384.DAT for mode 2 and RUNI192.DAT for mode 3). The phase relations of the carriers in these files are not absolutely in line with the DAB standard. Reference files conforming to the standard and reference files for other numbers of carriers are easily generated using a text editor or an auxiliary program. For an example file refer to the Annex.

A user-defined reference file contains the following specifications:

- No. of carriers
- Consecutive numbering of the carriers
- Phase relations of the carriers in RAD (Range of values 0 to $6.28318 = 2\pi$)

A reference file has the following structure:

Header: REFERENCE_FILE: *Number of carriers* ↵
Data: -*No. of carriers/2* *first phase value* ↵
...
0 *0 (phase value is not considered)*
...
+*No. of carriers/2, last phase value* ↵

No. of carriers or No. of carriers/2 substitutes for the associated integer number.

The supplied program RUNINSWP.EXE generates phase reference files for a random number of carriers, the phase relations of all carriers being distributed such that the peak value of the symbol is as low as possible.

5.3 Structure of a User File *.USR

A user file can be loaded using menu item "Load data file". The parameters set for a symbol are updated automatically.

A user-defined data file includes the following entries:

- Type of data file (polar or rectangular)
- Number of carriers
- Carrier spacing
- Number of amplitude levels
- Number of phase steps
- Number of symbols per frame
- Length of guard interval
- Consecutive numbering of carriers
- Data values in rectangular or polar coordinates

User file divided into header and data section:

Header: USER_FILE:*type of value* ↵
 nbr_carr:*number of carriers*↵
 carr_spacing:*value*↵
 ampl_levels:*value*↵
 phase_steps:*value*↵
 nbr_sym_frame:*value*↵
 guard_int:*value*↵

Data section: -*No. of carriers/2, first amplitude- or x- value, first phase- or y-value*↵
 ...
 0,0,0
 ...
 No. of carriers/2, last amplitude- or x-value, last phase- or y-value↵

- for type of value, "polar" or "rectangle" are used as key words
- for number of carriers or number of carriers/2, the respective integer number must be used
- the data values must be specified with 5 digits after the comma
- the order of the pair of values Ampl./Phase or x-value/y-value is also important

Sticking to this structure is indispensable for proper functioning. During installation, the example files "REC180.USR", "POL180.USR" are copied to the \DATA directory. For more details on the example files, see Annex.

5.4 Structure of a Symbol File

The symbol files are generated automatically and saved as ASCII files with the file name extension "*.SYM". These files contain the time characteristics of the signal calculated from the phase and amplitude values of all carriers, split up into I and Q component.

The file header is made up of the lines "length_of_symbol:*Symbol length*" and ":carriers:*number of carriers*", followed by the data values of the I component and again the line "length_of_symbol:*Symbol length*" and "carriers:*number of carriers*" followed by the values for the Q component. The values are saved with sign and 7 digits. An example file is provided in the Annex.

5.5 Structure of a Sequence File

The sequence files are generated automatically and saved as ASCII files with the file name extension "*.SEQ". The file header consists of the line "ADS sequence: *No. of symbols* symbols". *No. of symbols* substitutes for the numeric value of the number of symbols per frame. Then the data values of the sequence of the I component are stated, each symbol being completely defined in one line, ie with signal and guard components. The values consist of wave numbers (ARB numbers) with repetition factor and individual read clock period (expansion factor) for I or Q symbol component (see operating manual ADS). The next line is again "ADS sequence: *No. of symbols* symbols" followed by the wave numbers of the Q component. For example files, refer to the Annex.

6 Example of How to Use the Program

This section introduces you step by step to the use of the DAB-K1 program. We encourage you to work through these instructions at least once.

1. Interface the ADS to the IEC/IEEE bus of your computer. Connect the ADS signal outputs to the I and Q modulation inputs of the SMHU 58. Turn on your computer and the measuring instruments. Switch the SMHU 58 to I/Q modulation and set the desired signal center frequency. Make sure the ADS is set to IEC bus address 14. When no ADS is currently available, only the calculation and saving of symbols is possible.
2. Change to the directory containing the DAB.BAT program file and the \DATA subdirectory. Start program DAB.BAT. The program checks whether the ADS can be addressed via IEC/IEEE bus and the available memory capacity.
3. Select the desired DAB mode 1, 2 or 3 or the "User defined" mode in the "Mode" menu. If you have selected "user defined", specify the signal as you desire or load an appropriate file using "Load data file".
4. Change to the "Calc. Symbol" menu and select the appropriate options for "Phase Ref. Symbol" and "Modulation".
5. If you desire the calculation of a symbol with amplitude distortion or phase distortion, make the necessary entries in the associated menus.
6. Start the calculation of a symbol by selecting menu item "Calc. Symbol". A file MAXPOWER.TXT is created, containing the power distribution of the calculated symbol. This file can be edited at a later date using any text editor.
7. The calculated symbol can now be stored to your hard disk using menu item "Save Symbol". In doing so, enter a name for the symbol, consisting of no more than 8 characters. The file extension *.SYM is automatically appended. The file is saved in the \DATA subdirectory. In case you desire a different subdirectory, enter the complete path.
8. Repeat the steps 5 to 7 for the number of symbols you desire. The symbols being modulated or distorted with random sequences, each calculation results in a different symbol.
9. Now change to the "Calc. Sequence menu" and select whether you want a time reference symbol (null symbol) to be considered in the calculation. Enter the number of symbols to be combined to form a sequence (count in the null symbol and phase reference symbol).
10. Start the calculation of the sequence by selecting menu item "Calc. Sequence".
11. The calculated sequence can now be stored to your hard disk using menu item "Save Sequence". In doing so, specify a name for the sequence, consisting of no more than 8 characters. The file extension *.SEQ is automatically appended. The file is saved in the \DATA subdirectory. In case you desire a different subdirectory, enter the complete path.
12. Repeat the steps 9 to 11 when you intend to calculate more than one sequence.
13. Now, you may start transfer of the data to the connected ADS. To this end, change to the "Transfer" menu. Set the ARB number of the symbol to be subsequently transferred using menu item "ADS Parameters", eg number 08. Make sure the guard interval is set to the correct value; if required, you may enter the desired value in the "Mode" menu, submenu "User defined". Signal and guard portions of the I and Q components of the symbols are automatically split up among the following ARB numbers.
14. Start the transfer of a symbol by selecting menu item "Transfer Symbol". The symbol currently available in the computer memory and whose name is read out on the screen display field in the extreme right column is transferred.

15. If you desire to transfer further symbols, calculate or load them first (step 6). For loading symbols, change to the "Calc. Symbol" menu and select menu item "Load Symbol" and then the desired symbol file.
16. Change again to the "Transfer" menu and set the ARB number of the symbol to be transferred next, eg number 12, using menu item "ADS Parameters".
17. Start the transfer of the symbol by selecting menu item "Transfer Symbol" again.
18. Repeat the steps 15 to 17 for the number of symbols in the sequence.
19. Now, you may start the transfer of the sequence to the connected ADS. To this end, change to the "Transfer" menu. Set the sequence number of the sequence to be subsequently transferred using menu item "ADS Parameters", eg number 00.
20. Start the transfer of a sequence by selecting menu item "Transfer Sequence". The sequence currently available in the computer memory and whose name is read out on the screen display field in the extreme right column is transferred.

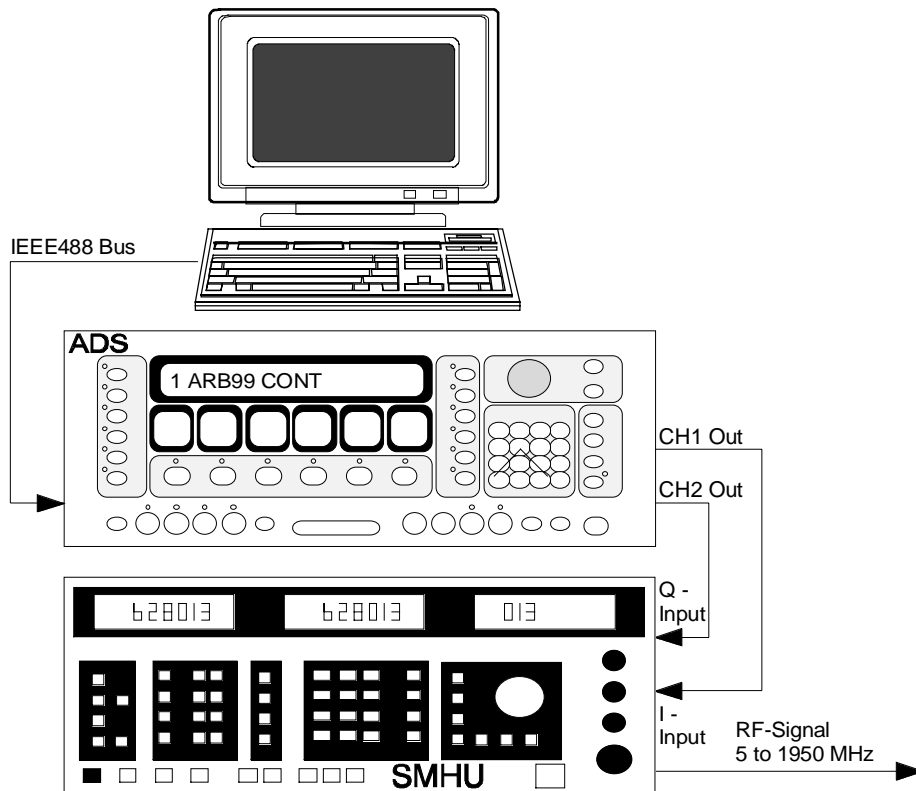
The ADS outputs the signals of the transferred sequence immediately to the outputs CH1 and CH2. The levels are selected such that the dynamic range of the SMHU 58 is optimally used. SMHU 58 permits the center frequency of the modulated signal as well as the total level to be altered at a later date. The modulated RF signal is applied to the output of SMHU 58.

7 Annex

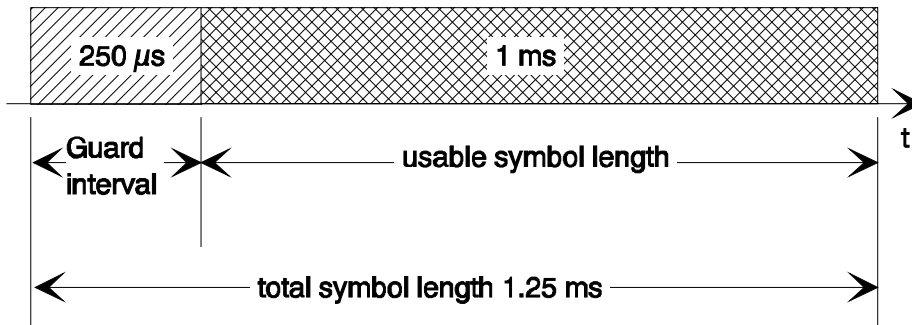
7.1 Interconnecting the Instruments

Connect the ADS output CH1 to the I input of SMHU 58 and the ADS output CH2 to the Q input of SMHU 58. If the modulation signals are to be locked in phase to the carrier signal of SMHU 58, also connect the 10-MHz reference frequency output to the input for external reference "REF 5/10 MHz" of ADS and set ADS to "external reference".

Interface the computer to the ADS via IEC/IEEE bus and set the IEC/IEEE address of ADS to 14. IEC/IEEE bus control of SMHU 58 is not provided.



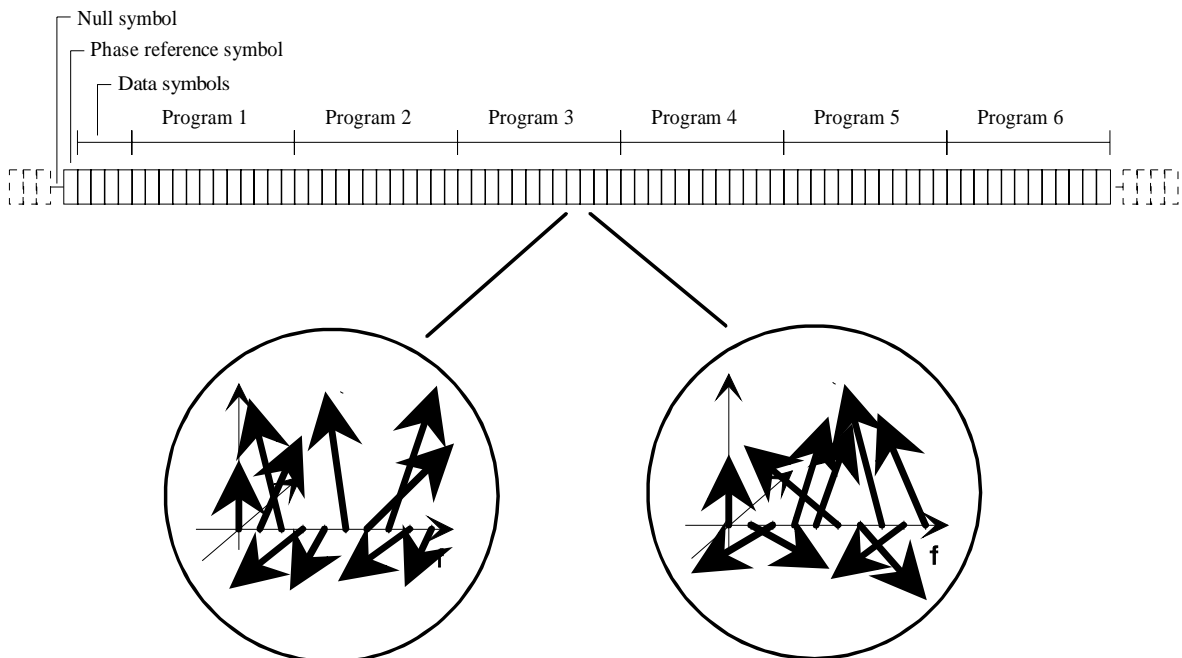
7.2 Time Characteristic of a DAB Symbol



The specified values are in conformance with a preliminary DAB specification for mode 1. With the usable symbol length being generated by 2048 data words, the guard interval must be set to 512 clocks when it is to take 250 μs. The time characteristic during the guard interval is the same as at the end of the usable symbol length. In order to save memory capacity in the ADS each symbol is broken down into a signal component which is not repeated and the guard component. In the sequence, these components are combined again in the correct order and output in the sequence guard component, non-repeated signal component and again guard component.

7.3 Time Characteristic of DAB Frame

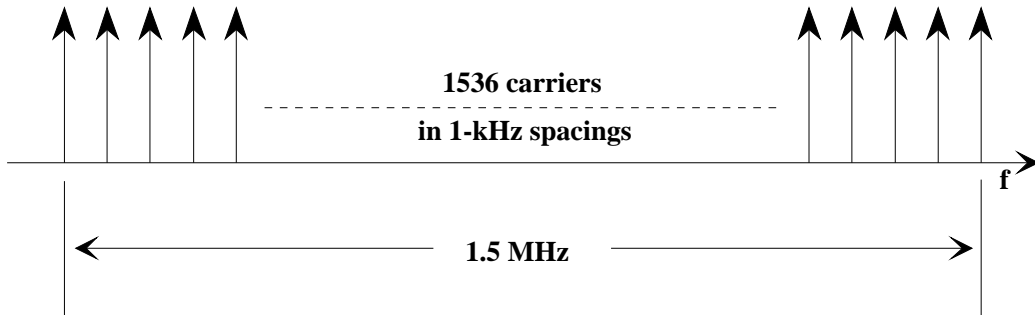
A DAB frame begins with a null symbol succeeded by a phase reference symbol. It is followed by 75 symbols with modulation in mode 1 and 2 or 142 symbols in mode 3. These DAB frames are simulated by a sequence of symbols which is output repetitively.



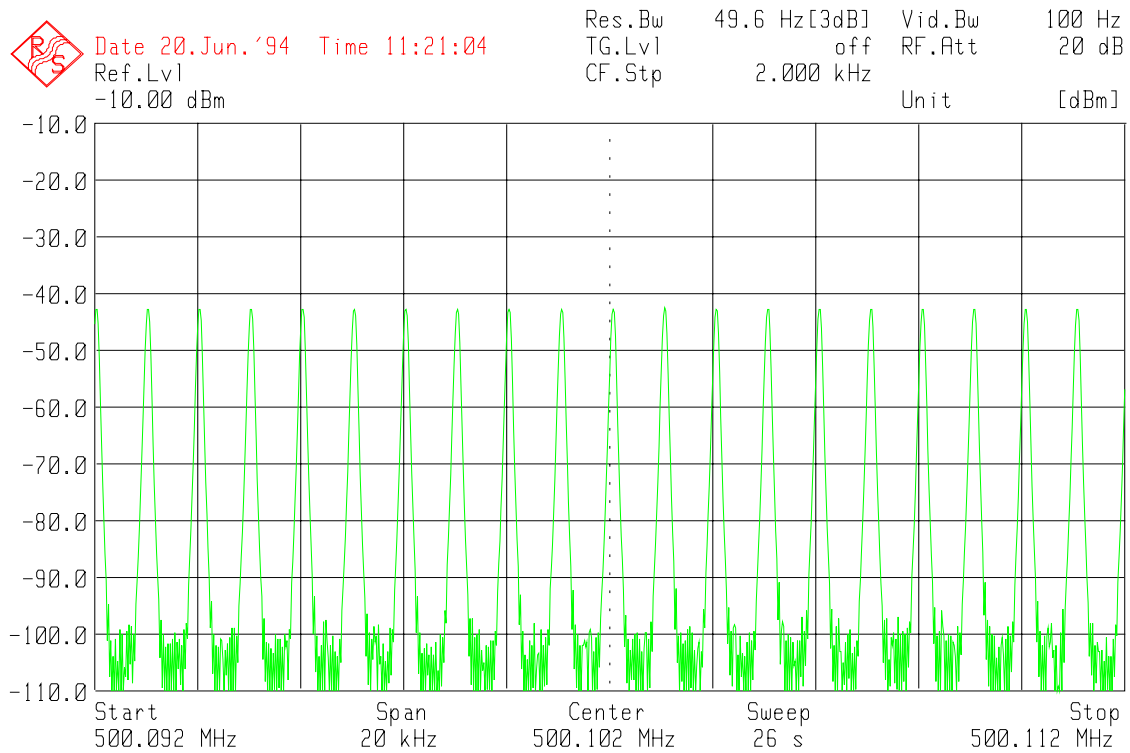
Frame in Mode 1 and Mode 2 with phase modulation of the individual carriers

07.24 Spectrum and Time Characteristic of a DAB Signal (Example Mode 1)

The chart below illustrates the spectrum of a DAB signal in mode 1 not taking into account the carrier phase relations:

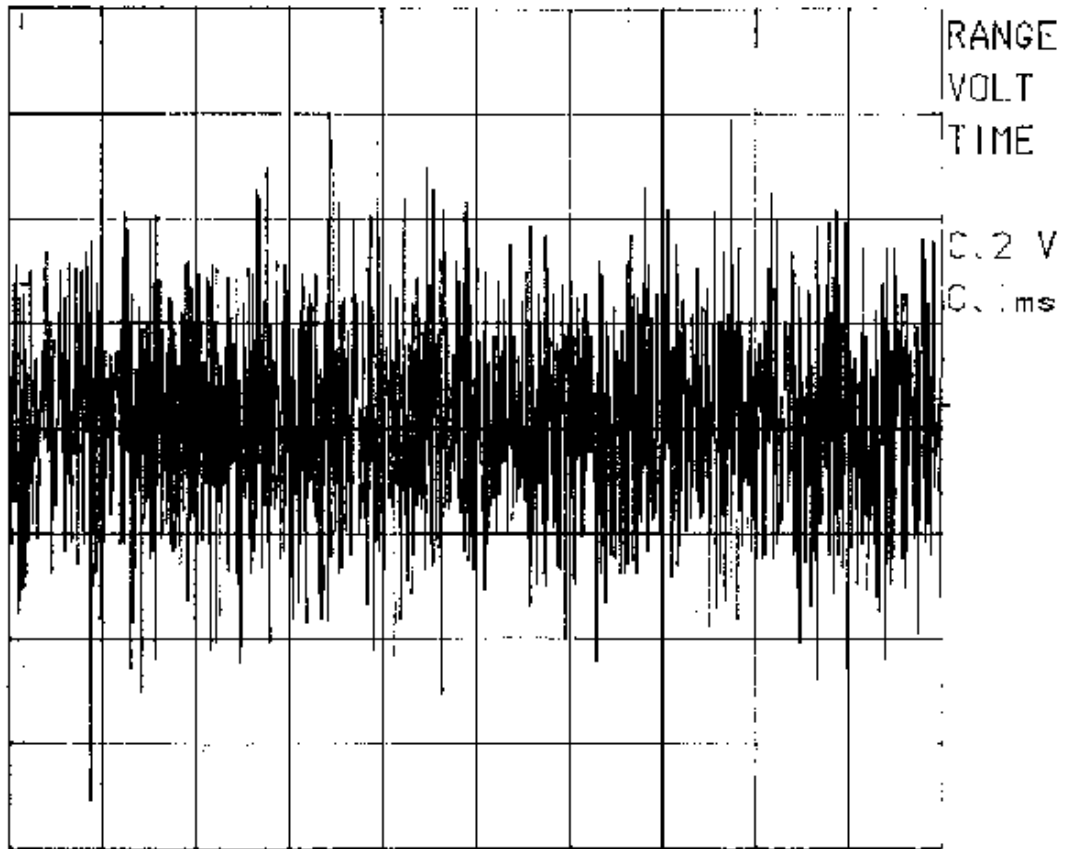


The following chart shows a section from a spectrum measured using the Rohde & Schwarz Spectrum Analyzer FSA.



Measured spectrum of a COFDM signal

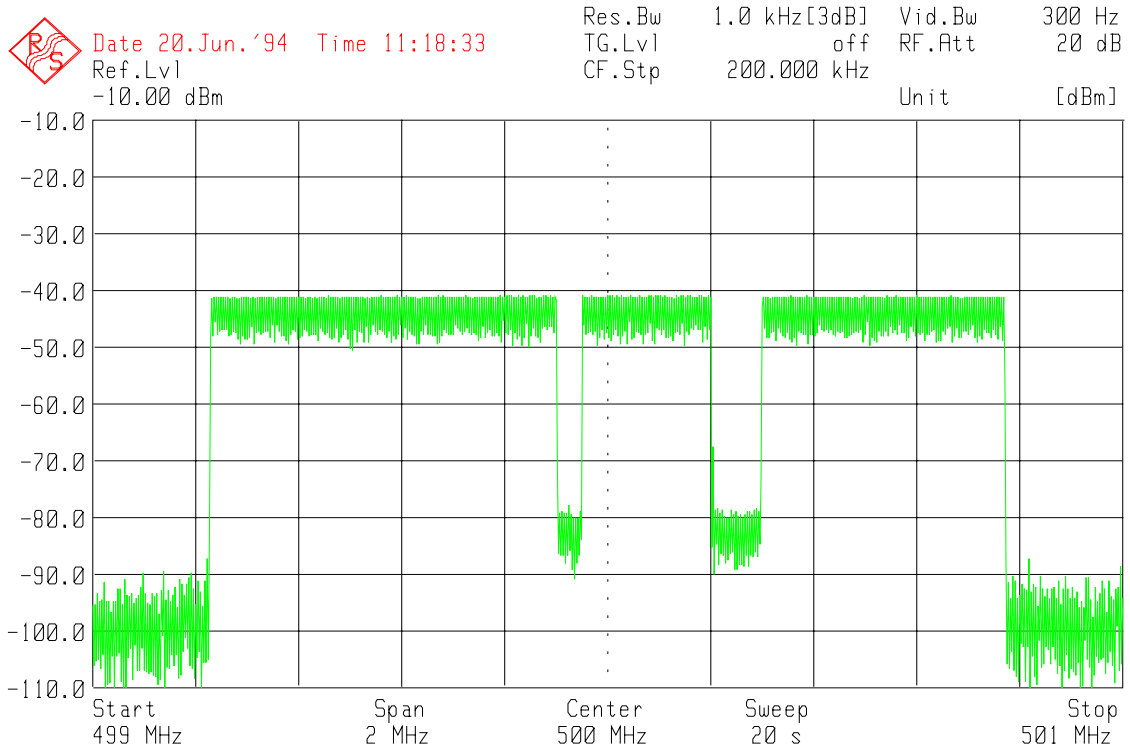
The time characteristic for the I and Q components of this signals is very similar to noise. The following chart shows an oscillogram of an I signal in DAB mode 1 (without guard interval):



Oscillogram of the time characteristic of a DAB mode 1 signal

07.35 Spectrum of a DAB Signal with Fading (Example Mode 1)

The spectrum of a DAB signal in mode 1 with two fading ranges faded in is shown by the following chart (measured with the Rohde & Schwarz Spectrum Analyzer FSA):



COFDM signal with fading distortions

7.6 Parameters of the DAB Modes

Parameter	Mode 1	Mode 2	Mode 3
Number of carriers	1536	384	192
Carrier spacing	1 kHz	4 kHz	8 kHz
Clock rate ADS(= 1/T)	2.048 MHz	2.048 MHz	2.048 MHz
Symbol length (incl. guard interval)	$(2048 + 512)*T = 1.25$ ms	$(512 + 128)*T =$ 0.3125 ms	$(256 + 64)*T =$ 0.15625 ms
Guard interval	$512*T$	$128*T$	$64*T$
Null symbol	1 ms	0.25 ms	0.125 ms
Frame	96 ms	24 ms	24 ms
Number of symbols per frame (incl. null symbol)	77	77	144
Number of data words for 1 symbol in the ADS	2048	512	256

The above table sums up the significant parameters of the DAB modes. All values being preliminary, planned values, the values finally specified in the DAB specification may be slightly different.

7.7 Relationship between Number of Carriers and Required Memory Capacity

Time characteristics of the symbols and thus the data to be stored in the ADS are calculated using an "Inverse Fast Fourier Transformation" (IFFT) with the base 2^n , n being an integer. The following applies: 2^n must be higher than or equal to the number of carriers. With this IFFT, a complex time signal consisting of 2^n data words for the I and the Q components, respectively, is calculated. It requires 2^n memory locations in each ADS channel.

If the transformation type DFT is selected, the symbols are calculated using "Inverse Discrete Fourier Transformation" (IDFT). The symbol length of this transformation is freely selectable and may comprise up to 8192 points. It is useful to select 1.2 times the number of carriers.

Each ADS channel has a memory capacity of 16384 (ADS 16k) or 65536 (ADS 64k) words.

Example FFT: a number of carriers = 1536 results in 2048 for 2^n , the ARB waves for the I and Q components have a length of 2048 points each. In a 16k-ADS, 8 symbols can thus be saved.

Example DFT: With a carrier number = 1536 the symbol length 1800 may be selected, the ARB waves for the I and Q component having a length of 1800 points each. 9 symbols can thus be stored in a 16k ADS.

When a guard interval is required, the signal sequencer integrated in the ADS can be taken advantage of. The time characteristic during the guard interval is also included as part of the time characteristic during the actual symbol length. In order to save memory capacity the ARB wave of the signal is separated into two waves. The time characteristic of the guard interval is split off and saved for example in ARB wave number 10. The remaining part of the signal is saved in a second ARB wave, eg in number 08. The signal is now output in a sequence, consisting of ARB wave 10, wave 08 and again wave 10. This allows the saving of valuable memory capacity. Since each symbol consists of an I and a Q component, which are to be stored in

different ARB waves, each symbol requires 4 ARB numbers. A maximum of 100 different ARB waves can be stored in the ADS (ARB wave numbers 00 to 99).

7.8 Example Files

The following section provides excerpts from several example files.

07.38.1 Configuration File

Example of a configuration file for DAB mode 1, file name "M1.CFG":

```
DAB-K1 Configuration:
*****
DAB Mode
0                               Mode 0/1/2/3/ 0 = user defined
1536                            Number of Carriers
1                               Carrier Spacing in kHz
1                               Amplitude Steps (DAB = 1)
4                               360 / 4 Phase Steps (90/180/270/360)
504                             Guard Intervall in T
2048                            Symbol Length
77                              Number of Symbols per Frame
8                               max. Number of Symbols per Sequence
*****
Calculation Parameters
1                               Time Ref. Symbol (0 = no / 1 = yes)
1                               Phase Ref. Symbol (0 = no / 1 = yes)
0                               Amplitude Distortion (0 = no / 1 = yes)
0                               Phase Distortion (0 = no / 1 = yes)
0                               Value of Amplitude Distortion in Percent
0                               Amplitude Fading 1 from
0                               Amplitude Fading 1 to
0                               Amplitude Fading 2 from
0                               Amplitude Fading 2 to
0                               Phase Distortion in DEG
1                               Modulation (0 = no / 1 = yes)
1536                            Clipping Power = Number of Carriers * Thermal Power
*****
Miscellaneous Parameters
2.048                           Clock Rate in MHz
8                               ARB Number
0                               Sequence Number
12                              D/A Converter Resolution (bits)
*****
```

7.8.2 Phase Reference File

Example of a phase reference file in DAB mode 1 with 1536 carriers, file name "RUNI1536.DAT":

<i>File contents</i>	<i>Meaning</i>
REFERENCE_FILE: 1536	<i>Header with number of carriers</i>
-768 3.926991	<i>Carrier number and phase value for carrier -768</i>
-767 3.141593	<i>Carrier number and phase value for carrier -767</i>
-766 3.141593	
.....	<i>Phase value in RAD with 6 digits after the comma</i>
-2 2.356194	<i>Range of values 0 to +6.28318 (2π) RAD</i>
-1 4.712389	
0 2.356194	
1 4.712389	
2 0.785398	
3 3.926991	
.....	
767 4.712389	
768 3.141593	

7.8.3 User-defined Files

Example of a specification using polar coordinates "POL180.USR":

<i>File contents</i>	<i>Meaning</i>
USER_FILE:polar	<i>Header for user file in polar coordinates</i>
nbr_carr:180	<i>Number of carriers</i>
carr_spacing:1	<i>Carrier spacing in kHz</i>
ampl_levels:1	<i>Number of amplitude levels (= 1 for DAB signals)</i>
phase_steps:4	<i>Number of phase steps (= 4 for DAB signals)</i>
nbr_sym_frame:77	<i>Number of symbols for a frame</i>
guard_int:64	<i>Guard interval in number of data words</i>
*****	<i>Separation between header and data</i>
-90, 0.5570612, 0.2234631	<i>Carrier number, amplitude value, phase value for carrier -90</i>
-89, 0.5570612, 0.2234631	<i>Carrier number, amplitude value, phase value for carrier -89</i>
-88, 0.5570612, 0.2234631	
-87, 0.5570612, 0.2234631	<i>Range of values for amplitude values 0 to 1 with 5 digits after the comma</i>
-86, 0.5570612, 0.2234631	
-85, 0.5570612, 0.2234631	<i>Range of values for phase values 0 to 2π (6.28318) RAD</i>
-84, 0.5570612, 0.2234631	<i>with 7 digits after the comma</i>
.....	

The range of values for the amplitude values is 0 to 1, the range of values for the phase values is 0 to 2 π (6.28318) RAD. 5 digits after the comma are considered in each case. When the calculated time signals are output to the ADS, scaling is performed automatically to bring the signals within the dynamic range of ADS and SMHU 58.

Note: All carriers used in this example have the same amplitude and phase relation, resulting in a pulse-shaped time characteristic of the signal provided that the phase relations are not altered by an additional modulation.

Example of a specification using rectangular coordinates, file name "RECT180.USR":

<i>File contents</i>	<i>Meaning</i>
USER_FILE:rectangle	<i>Header for user file in rectangular coordinates</i>
nbr_carr:180	<i>Number of carriers</i>
carr_spacing:1	<i>Carrier spacing in kHz</i>
ampl_levels:1	<i>Number of amplitude levels (=1 for DAB signals)</i>
phase_steps:4	<i>Number of phase steps (=4 for DAB signals)</i>
nbr_sym_frame:77	<i>Number of symbols for a frame</i>
guard_int:123	<i>Guard interval in number of data words</i>
*****	<i>Separation between header and data</i>
-90, 0.5432145, 0.1234567	<i>Carrier number, X value, Y value for carrier -90</i>
-89, 0.5432145, 0.1234567	<i>Carrier number, X value, Y value for carrier -89</i>
-88, 0.5432145, 0.1234567	
-87, 0.5432145, 0.1234567	<i>Range of values for X and Y values -1 to +1 with 7 digits</i>
-86, 0.5432145, 0.1234567	<i>after the comma</i>
-85, 0.5432145, 0.1234567	
-84, 0.5432145, 0.1234567	<i>Automatic scaling is performed</i>
.....	<i>on the basis of the dynamic range of SMHU 58</i>

The range of values for the X and Y values is 0 to ± 1 . 5 digits after the comma are considered in each case. When the calculation is performed automatically to avoid exceedings of the dynamic range of ADS and SMHU 58.

This file generates the same signal as the POL180.USR file.

7.8.4 Sequence File

Example of a sequence file taking into account guard intervals, null symbol and phase reference symbol, file name "MODE1.SEQ":

<i>File contents</i>	<i>Meaning</i>
ADS sequence:77 symbols	<i>Header with number of symbols, beginning of the sequence of I component</i>
02,1,1, 00,1,1, 02,1,1	<i>I component of symbol with guard component which was transferred to ARB number 00 (with DAB null symbol), occurs only once in the sequence</i>
06,1,1, 04,1,1, 06,1,1	<i>I component of symbol with guard component which was transferred to ARB number 04 (with DAB phase reference symbol), occurs only once in the sequence</i>
22,1,1, 20,1,1, 22,1,1	<i>I component of symbol with guard component which was transferred to ARB number 20, also randomly repeated in the sequence</i>
18,1,1, 16,1,1, 18,1,1	<i>I component of symbol with guard component which was transferred to ARB number 16, also randomly repeated in the sequence</i>
30,1,1, 28,1,1, 30,1,1	
14,1,1, 12,1,1, 14,1,1	
10,1,1, 8,1,1, 10,1,1	
.....	
ADS sequence:77 symbols	<i>Header with number of symbols, beginning of the sequence of Q component</i>
03,1,1, 01,1,1, 03,1,1	<i>Q component of symbol with guard component which was transferred to ARB number 00 (with DAB null symbol), occurs only once in the sequence</i>
07,1,1, 05,1,1, 07,1,1	<i>Q component of symbol with guard component which was transferred to ARB number 04 (with DAB phase reference symbol), occurs only once in the sequence</i>
23,1,1, 21,1,1, 23,1,1	<i>Q component of symbol with guard component which was transferred to ARB number 20, also randomly repeated in the sequence</i>
19,1,1, 17,1,1, 19,1,1	<i>Q component of symbol with guard component which was transferred to ARB number 16, also randomly repeated in the sequence</i>
31,1,1, 29,1,1, 31,1,1	
15,1,1, 13,1,1, 15,1,1	
.....	

7.8.5 Symbol Files

The calculated symbol files have the following structure:

<i>File contents</i>	<i>Meaning</i>
length_of_symbol:2048	<i>Header with specification of symbol length</i>
carriers:1536	<i>Header with number of carriers</i>
0.14160	<i>1. Amplitude value of time characteristic, I component</i>
-0.07669	<i>2. Amplitude value of time characteristic, I component</i>
-0.35122	
0.04293	
-0.05404	
-0.41874	
.....	
length_of_symbol:2048	<i>Header with specification of symbol length</i>
carriers:1536	<i>Header with number of carriers</i>
-0.37160	<i>1. Amplitude value of time characteristic, Q component</i>
-0.14826	<i>2. Amplitude value of time characteristic, Q component</i>
0.00993	
-0.31074	
-0.30114	
0.12691	

7.9 Calculation of Special Symbols

In the following section, you will find information on the calculation of null symbols (time reference symbols) and phase reference symbols (time-frequency-phase reference symbols) as well as of symbols with carrier numbers near 2^{N} .

7.9.1 Calculation of a Null Symbol (Time Reference Symbol)

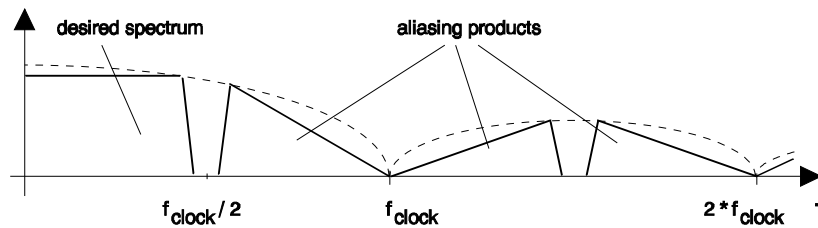
For calculation of a null symbol, first select the DAB mode you desire. Then switch Fading ON for all carriers in the "Ampl. Distortion" menu, which sets all carrier amplitudes to zero. Start the symbol calculation using "Calc. Symbol" and save the calculated symbol, for example, under the name "null1536.sym". You can check this file using a text editor, all data values have to be zero. In the "User defined" menu, you can specify a guard component for the null symbol. Now transfer the symbol with the selected guard component to ARB number 00 in the ADS (the ARB number is set in the "ADS Parameters" menu). I and Q components of the symbol as well as the signal or guard components are automatically split up among the ARB numbers 00, 01, 02 and 03. Check the number of data words of the ARB waves at the ADS and make sure that all data values have an amplitude of zero. This verification also gives you a more profound insight into the functioning of the program.

7.9.2 Calculation of a Phase Reference Symbol (Time-Frequency-Phase Reference Symbol)

Analogously to the calculation of a null symbol, first select the desired DAB mode. Switch the modulation OFF in the "Calc. Symbol" menu. Now start the symbol calculation using "Calc. Symbol" and save the calculated symbol, eg under the name "REF1536.SYM". In the "User defined" menu, you can specify a guard component for the phase reference symbol. Transfer this symbol with the selected guard component to the ADS in the ARB number 04 (the ARB number is set in the "ADS Parameters" menu). I and Q components of the symbol as well as the signal or guard components are automatically split up among the ARB numbers 04, 05, 06 and 07.

7.9.3 Calculation of Symbols with Carrier Numbers Near 2^n

The symbols are calculated using a "Fast Fourier Transformation" (FFT). This FFT converts 2^n values in the frequency domain into 2^n values in the time domain, n being a positive integer. Hence, values of 128, 256, 1024 etc. result for 2^n . These 2^n values in the time domain are read out of the ADS with the set clock frequency. Physically, a spectrum can be generated extending from DC voltage to half the clock frequency. However, this spectrum is replicated adjacent to the clock frequency and then additionally output, that is to say, when a spectral line of 1 kHz is desired, spectral lines at the clock frequency minus 1 kHz and at the clock frequency plus 1 kHz are obtained at the same time. These additional spectral lines are termed aliasing products. In general, they are removed by filtering with a lowpass of the cutoff frequency equal to half the clock frequency. In practice, this lowpass cannot be built as steep-edged as desired. This means that when spectral lines closely below half the clock frequency are to be generated, the aliasing products cannot be filtered out adequately.



A very elegant solution to this problem is to double both the clock frequency and the number of carriers while not using the higher frequency half of the carriers.

If you desire to generate, for example, 250 carriers using the DAB-K1 program, the problems described above would arise. In order to avoid them, double the number of carriers to 500. The program then selects an FFT with the base $2^9 = 512$, allowing the generation of the carriers -256 to +256. Fade out the undesired carriers from -256 to -126 and +126 to +256 using the two fading ranges in the "Ampl Distortion" menu.

Another possibility is to use the transformation type DFT. If, when using the DFT, the symbol length is set to values greater than 1.2 times the number of carriers, the aliasing products can be easily suppressed using lowpass filters between ADS and SMHU 58.

The $\text{SIN}(X)/X$ -wave amplitude drop illustrated in the figure is automatically compensated for in the calculation of the time characteristic of the symbols.

7.10 Modulation of SMHU 58 with a Single Symbol

For testing purposes, you may use only a single symbol, eg the phase reference symbol, for the modulation of the SMHU 58. In this case, proceed as follows:

Determine the ARB numbers in which the symbol is stored in the ADS; a phase reference symbol, e.g. is stored in the ARB numbers 04 05, 06 and 07. For further operation, make your settings directly at the ADS. Create a sequence for output of the I component (eg sequence no. 10) from the ARB waves No. 06, 04 and 06. Create a second sequence for output of the Q component (eg sequence no. 11) from the ARB waves No. 07, 05 and 07. Set CH1 at the ADS to output of the first sequence (sequence no. 10) and CH2 to output of the second sequence (sequence No. 11). Now, you obtain a signal with guard component at the SMHU 58. A signal without guard component can be obtained from it by deleting the first element (ARB wave No. 06 to 07) in each of the sequences No. 10 and 11.

As an alternative, the program offers you the possibility of calculating a sequence with one symbol only. Please note that in this case, you must switch off both the null symbol and the phase reference symbol using the associated menu items. Then a sequence is calculated, outputting the symbol stored in wave No. 08 when a guard interval is switched on. Alternatively, the symbol saved in ARB wave No. 04 is output when the guard interval is set to 0 T. This symbol is then output cyclically, which means that the set number of symbols per frame is without significance.

When transferring a symbol with guard interval $\neq 0$, the sequences 98 and 99 are automatically formed for CH1 (I signal) and CH2 (Q signal). If this symbol is to be used without guard interval, the first element of the sequences 98 and 99 is to be deleted in each case.

7.11 Files Supplied with DAB-K1

The program diskette contains the files INSTALL.EXE and DAB____.EX_.

The program itself consists of the following program files which you will find after program installation in the specified directories on your hard disk on the drive you have selected :

Directory \DAB:

DAB	.BAT	Batch file for starting the program
DAB_K1	.EXE	Program file
HELV8	.GFN	Help file
EGA	.GFN	Help file
README	.TXT	Notes on the program with the latest supplements
USER	.BAS	Example file for generation of user files (programming language Basic)

and the following example files:

Directory \DAB\DATA:

DEFAULT	.CFG	Example of a configuration file (default setting of DAB-K1)
180	.CFG	Example of a configuration file for the user files POL180.USR and REC180.USR
MODE1	.CFG	Example of a configuration file in DAB mode 1
MODE2	.CFG	Example of a configuration file in DAB mode 2
MODE3	.CFG	Example of a configuration file in DAB mode 3
USER	.CFG	Example of a configuration file in User mode
RUNI1536	.DAT	Phase reference file for DAB mode 1 *)
RUNI384	.DAT	Phase reference file for DAB mode 2 *)
RUNI192	.DAT	Phase reference file for DAB mode 3 *)
MODE1	.SEQ	Example of sequence file for DAB mode 1
NULL1536	.SYM	Example of null symbol for DAB mode 1 *)
NULL_384	.SYM	Example of null symbol for DAB mode 2 *)
NULL_192	.SYM	Example of null symbol for DAB mode 3 *)
PHRE1536	.SYM	Phase Ref. Symbol for DAB mode 1, calculated from phase reference file RUNI1536.SYM *)
PHRE_384	.SYM	Phase Ref. Symbol for DAB mode 2, calculated from phase reference file RUNI_384.SYM *)
PHRE_192	.SYM	Phase Ref. Symbol for DAB mode 3, calculated from phase reference file RUNI_192.SYM *)
SYM01	.SYM	Examples of calculated modulated symbols
SYM02	.SYM	
SYM03	.SYM	
SYM04	.SYM	
SYM05	.SYM	
SYM06	.SYM	
POL180	.USR	Example of a user file in polar coordinates
REC180	.USR	Example of a user file in rectangular coordinates
RUNINSWP	.EXE	Program for generation of a phase reference file with selectable number of carriers with peak-value optimization.

*) The phase reference files must be regarded as examples. Their phase relations do not entirely comply with the DAB specification.

8 Glossary

This section gives you further explanations on frequently used terms.

Carrier	Each symbol consists of n simultaneously available carriers which are phase-modulated and, as the case may be, also amplitude-modulated. Modulation is constant during the entire length of the symbol, but changes from symbol to symbol.	Guard interval	Time interval used to avoid modulation distortions which may result from multipath transmission. The guard interval precedes any symbol, the time characteristic of the signal during the guard interval being the same as at the end of the signal.
COFDM	Coded Orthogonal Frequency Division Multiplex; modulation with many, simultaneously present, modulated carriers.	IDFT	Inverse Discrete Fourier Transformation
DAB	Digital Audio Broadcasting	IFFT	Inverse Fast Fourier Transformation
Data words	The FFT provides a sequence of data words, representing the time characteristic of the signal. Transferred to the ADS, the data words are converted into a time signal (voltage) using D/A converters. The number of data words is defined by the algorithm to a power of 2 (eg 256, 512, 1024, 2048, ...). This number also corresponds to the length of the ARB wave transferred to the ADS. When a guard interval is used, part of the data words are saved in the ARB wave of the guard interval.	RF carrier	Center frequency of the RF-converted and modulated signal. Due to the characteristics of the Signal Generator SMHU 58, this carrier is suppressed by 50 to 60 dB compared to the peak amplitude of the total signal. The carrier frequency can be set manually at the SMHU58 in the range from 5 MHz to 1950 MHz.
DFT	Discrete Fourier Transformation	Symbol	A symbol consists of n modulated carriers, the modulation contents of which remains constant for the length of the symbol.
DVB	Digital Video Broadcasting	Symbol length	Number of data words of a symbol, corresponds to the transformation length of the FFT or DFT.
FFT	Fast Fourier Transformation; algorithm for calculating the spectral components of a signal from its time characteristic. In the DAB-K1 program, the inverse algorithm, the "Inverse Fast Fourier Transformation" (IFFT) is used to calculate the time characteristic from the specified spectrum.		
Frame	Frames for DAB signals. A frame begins with a null symbol (time reference symbol), followed by a phase reference symbol (time-frequency-phase reference symbol) and a number of symbols containing modulation data.		

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