GPS Frequency Standard
HM8125

HM8125 GPSTime/Frequency-Standard

- **Ultra-preciseTime, Frequency and Position**
- **World-wide Operation**
- **Ultra-precise 10 Mhz Output**
- **Accuracy $1x10^{-12}$ when tracking Satellites**
- **Short-term stability $3x10^{-10}$ at 2 second IntegrationTime**
- **1 Pulse Per Second Output**
- **Serial Communication Port RS232**
- **Low Cost of Ownership**

The **HM8125** is a time/frequency standard designed to provide ultra-precise time, frequency and position. It is based on the **NAVSTAR Global Positioning System (GPS)**, developed and deployed by the U.S. department of defense. It is the most accurate radio navigation system ever developed and enables users, world-wide, to determine the correct time with a higher degree of accuracy than ever before.

The **HM8125** automatically acquires and tracks the **satellites** and calculates **time**, **frequency** and **position** within 2 to 15 min. after power-up. Synchronization is confirmed via a front panel LED indicator and the actual deviation can be read on a 2x20 characters LCD screen. The compact unit provides timing outputs to within **100 nanoseconds** of UTC (Selective Availability not implemented) and frequency outputs accurate to **$1x10^{-12}$** when tracking satellites. Time and position data are available on the **serial interface**. This enables the use of the **HM8125** in calibration set-ups with easy registration and documentation facilities.

The **HM8125** produces a **2.048 MHz** frequency output which is locked to the GPS system. This allows applications in the telecommunication and **PCM** field. The **HM8125** can also measure external frequencies with an accuracy of **$3x10^{-10}$** at a gate time of 1 second. For field applications, the geographic position can be read from the LCD screen. The **HM8125** can synchronize a **Rubidium Oscillator** and can operate as a stand-alone generator.

The **HM8125** is shipped as a complete set including the antenna, the converter and 15m of BNC cable.

Specifications

(Ref. temperatur : 23°C ± 2°C)

Frequency Generation

Frequency output:	1kHz, 2.048MHz and 10MHz
Accuracy:	$\pm3x10^{-10}$ at 2 seconds measuring time $\pm1x10^{-12}$ at 24 hours measuring time
Timing output:	1PPS (Pulse per Second)
Accuracy:	100ns to UTC or GPS time
Jitter:	<5ns
Position:	Latitude und Longitude (100m), Altitude (150m)
Accuracy:	(Under "Selective Availability enabled") ±5m horizontal; ±10m vertical (24 hours averaged)

Frequency measurement

Frequency input:	10 MHz ± 70ppm
Accuracy:	$3x10^{-10}$ at 2 seconds measuring time $2x10^{-10}$ at 0.2seconds measuring time
Input Sensitivity:	typ. 30mV - 1V
Antenna:	All-weather, outdoor mounting
Dimensions:	Ø 4cm x 12cm (approx.)
Frequency converter:	for cable runs up to 25m
Dimensions:	3cm x 7cm x 17cm (approx.)
Divers:	RS232 interface built-in DCF77 output
Power requirements:	110/220V ±15%; 45-60Hz, 45VA
Ambient temp.:	+10°C to +40°C
Humidity:	10%-90%, no condensation
Dimensions:	285mmx85mmx365mm (WxHxD)
Weight:	approx. 5kg
Safety:	Class I, According to IEC 1010-1

General Information

Immediately after unpacking, the instrument should be checked for mechanical damage and loose parts in the interior. If there is transport damage, the supplier must be informed immediately. The instrument must then not be put into operation.

Safety

This instrument has been designed and tested in accordance with **IEC Publication 1010-1** (overvoltage category I, pollution degree 2), Safety requirements for electrical equipment for measurement, control, and laboratory use. The CENELEC regulations EN 61010-1 correspond to this standard. It has left the factory in a safe condition. This instruction manual contains important information and warnings which have to be followed by the user to ensure safe operation and to retain the oscilloscope in a safe condition.

The case, chassis and all measuring terminals are connected to the protective earth contact of the appliance inlet. The instrument operates according to Safety Class I (three-conductor power cord with protective earthing conductor and a plug with earthing contact).

The mains/line plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action must not be negated by the use of an extension cord without a protective conductor.

The mains/line plug should be inserted before connections are made to measuring circuits.

Whenever it is likely that protection has been impaired, the instrument shall be made inoperative and be secured against any unintended operation. The protection is likely to be impaired if, for example, the instrument

- shows visible damage,
- fails to perform the intended measurements,
- has been subjected to prolonged storage under unfavourable conditions (e.g. in the open or in moist environments),
- has been subject to severe transport stress (e.g. in poor packaging).

Symbols


ATTENTION - refer to manual


Danger - High voltage


Protective ground (earth) terminal

Operating conditions

The instrument has been designed for indoor use.
The permissible ambient temperature range during operation is +10°C (+50°F) ... +40°C (+104°F). It may occasionally be subjected to temperatures between +10°C (+50°F) and -10°C (+14°F) without degrading its safety. The permissible ambient temperature range for storage or transportation is -10°C ... +70°C .
The maximum operating altitude is up to 2200m. The maximum relative humidity is up to 80%.

If condensed water exists in the instrument it should be acclimatized before switching on. In some cases (e.g. extremely cold oscilloscope) two hours should be allowed before the instrument is put into operation. The instrument should be kept in a clean and dry room and must not be operated in explosive, corrosive, dusty, or moist environments. The oscilloscope can be operated in any position, but the convection cooling must not be impaired. The ventilation holes may not be covered. For operation the instrument should be used in the horizontal position, preferably tilted upwards, resting on the tilt handle.

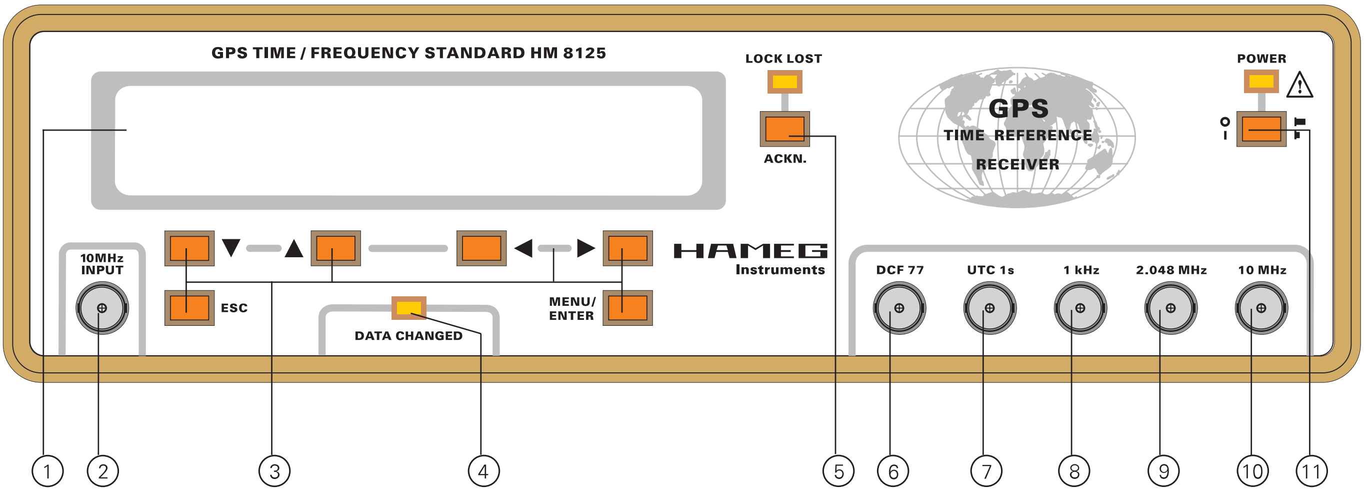
The specifications stating tolerances are only valid if the instrument has warmed up for 30minutes at an ambient temperature between +15°C (+59°F) and +30°C (+86°F). Values without tolerances are typical for an average instrument.

Warranty

HAMEG warrants to its Customers that the products it manufactures and sells will be free from defects in materials and workmaship **for a period of 2 years**. This warranty shall not apply to any defect, failure or damage caused by improper use or inadequate maintenance and care. HAMEG shall not obliged to provide service under this warranty to repair damage resulting from attempts by personnel other than HAMEG represantatives to install, repair, service or modify these products. In order to obtain service under this warranty, Customers must contact and notify the distributor who has sold the product.

Each instrument is subjected to a quality test with 24 hour "burn-in" before leaving the production. Practically all early failures are detected by this method. In the case of shipments by post, rail or carrier it is recommended that the original packing is carefully preserved. Transport damages and damage due to gross negligence are not covered by the guarantee. In the case of a complaint, a label should be attached to the housing of the instrument which describes briefly the faults observed. If at the same time the name and telephone number (dialing code and telephone or direct number or department designation) is stated for possible queries, this helps towards speeding up the processing of guarantee claims.

Controls for the HM8125



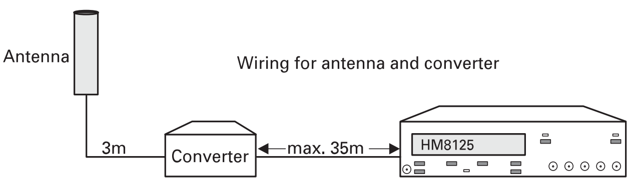
(1) LCD Display, 2x20 Symbols
(2) 10MHz Input for Frequency Measurements
(3) Menu Keys
(4) LED Indicator: "Data Changed"
(5) LED Indicator: "Lock-Lost"
Acknowledge Key
(6) DCF 77 Output
1 second Pulse, Square Wave
Output-Impedance: 1kΩ, 4Vpp
(7) UTC or GPS Timing Output
1pps (pulse per sec.), Square Wave
Output-Impedance: 1kΩ, 4Vpp
(8) 1kHz Output, Square Wave;
Output-Impedance: 1kΩ, 4Vpp
(9) 2.048MHz Output, Square Wave;
Output-Impedance: 50Ω, 2.5Vpp
(10) 10MHz Output, Square Wave;
Output-Impedance: 50Ω, 2.5Vpp
(11) Power On LED Indicator and Power Switch

Rear elements of the HM 8125

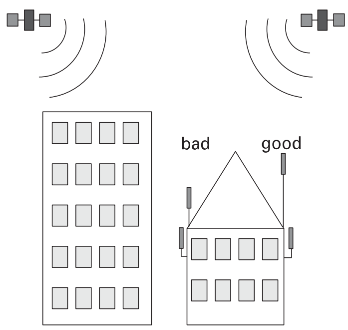
Mains Input, Voltage Selector and Fuse
Antenna Input Connector (BNC)
Relay Contact Output for "Lock-Lost"

Accessories Supplied with HM 8125

A HM 8125 receiver
B Frequency converter
C Antenna
D BNC to BNC cable 15 m (between converter and HM 8125)
E Type N to SMA cable 3 m (between antenna and converter)
F Adapter cable SMA to BNC (between converter BNC cable and HM 8125)
G BNC coupler (if D is BNC to BNC and not BNC to SMA)
H Manual, power cord and software for RS-232 interface



Wiring for antenna and converter



Position for antenna installation

Basic concept of the HM 8125 Frequency Standard

The HM 8125 is a time- and frequency-standard to generate highly precise time, frequency and position data. The accuracy is based on the NAVSTAR Global Positioning System (GPS) that was developed and is operated by the US Department of Defense. The GPS consists of 24 satellites with cesium standards to guarantee the accuracy. The satellite signals are transmitted worldwide. From these transmitted signals, the HM 8125 calculates its actual place of operation. Once this is found, the internal oscillators of the HM 8125 are slaved to the time standard of the GPS.

Installation

The HM 81215 instrument should be installed (if possible) in a climate-controlled area. The supplied 15 m BNC to BNC cable is connected between the connector on the rear of the instrument and to the remote antenna converter. This cable length can be extended up to 40 m and by use of an optional pre-amplifier to 100/ 200m. From the end of the BNC cable connect the BNC to SMA adapter cable to the antenna converter by use of the BNC coupler (Barrel). The antenna is connected by use of the type-N to SMA cable to the antenna converter. The antenna must be installed on a pole in a vertical position. The antenna converter must be installed within 3 m and preferably in a room. Even though the converter is in a weathertight enclosure, it will be better to give the converter the additional protection of a room or a separate enclosure. The power to the antenna is supplied via the coaxial cable from the antenna converter. The antenna must be installed to give a clear 180 degree horizontal field of view at the height of the antenna. No obstructions must be in front of the antenna to ensure optimum operation of the HM 8125.

GPS Reference Location

In general approximately 8 satellites are "visible" when the antenna location is optimum. To determine the accurate location of the HM 8125, four "visible" satellites are required. The internally stored location is at the final checkout (factory) of the HM 8125. This location will first come up upon initial use. Normally the initial "place" doesn't correspond to the actual "place" at the operation location. During initial use of the HM 8125, it may take up to 30 minutes to determine the geographic reference coordinates of the newly installed HM 8125. This time period is strongly dependent upon the "visibility" of the satellites. The duration of initial geo-referencing can be shorted by entering the known coordinate data of the actual location.

Getting Started

The following instructions are meant as a guideline to quick and easy setup the HM 8125 for the initial operation. To start operation the above given installation instructions must be observed. The initial position by default is the geographical location of the Hameg factory in Frankfurt, Germany. This position is used as the initial position by the instrument after power-up on delivery. When the installation has been done correctly and the antenna has a good "view" on the satellites, the instrument should lock after approx. 15 min. regardless of the operation location. However, in some cases when the installation of the antenna is not optimum, the unit may fail tracking sufficient satellites for locked operation.

In this case the following instructions might possibly help to set-up the instrument correctly.
Be sure to have the geographical location data of your position on hand. A tolerance of 1,5 oder 5° degree is acceptable. After "Power-on" the main menu appears on the LCD.

```
HM8125  GPS STANDARD
TIME FREQ RECVR STAT
```

Press the "RECVR"-key to access the "Receiver"-menu.

```
     RECEIVER:
TRACK USE  POS
```

By pressing the "USE"-key the "Use"-menu is reached.

```
USE averag'd position
 (using inital pos)
```

Due to the reason that the instrument cannot use the "averaged" position unless it has precisely located 4 satellites, the "entered" position mode should be used in the beginning. Pressing the "up"-key twice prepares the use of the position of the actual location.

```
USE entered position
 (using inital pos)
```

After confirmation by means of the "Enter"-key, the LCD changes to:

```
USE entered position
 (not yet verified!)
```

This menu is left via "ESC". In the "RECVR"-menu which appears now, press the "POS"-key, which displays the "POS"-menu.

```
entered:50°05.297'N
 0118m  008°38.813'E
```

The display shows the geographical position of Frankfurt, Germany. Use the "UP"-key (press twice) to change to "entered" and move to the digit which should be modified by means of the "left/right" keys.. To toggle between the digits to be modified use the "UP"/DOWN"-keys.

After the approximate position is entered press the "Enter"-key for confirmation. The main menu appears again. If the hardware installation is done correctly, the HM 8125 should lock now in a few minutes.

Operation

Besides the instructions in the "Getting started" section, operation of the HM 8125 does not require any further actions. Nevertheless some additional information should be taken into account to make proper use of the instruments features.

The operation of the HM 8125 is accomplished by commands that are entered via keys and a straight forward menu structure. All commands are resident in different menus and accessible via four cursor-keys (left/right and up/down). The four cursor (arrow) keys select the displayed entry above the keys, which vary from menu to menu. The four main menus designate sub-menus which will lead to additional functions. Data which need to (or can) be changed are underlined by a cursor to allow the change in the underlined position.
As soon as the HM 8125 is configured for its place of operation, subsequent operation is limited to monitoring the proper operation. The provided software allows this monitoring of the HM 8125 to take place via the RS-232 interface.

After the equipment is powered up, the main menu will appear and the Lock-Lost LED will blink. This LED will quit blinking after all internal oscillators are synchronized and the LED will remain permanently lit (Lock O.K.). This mode may be canceled after the LED is permanently lit by pressing the ACKN. key.

Specific operating modes can be established on power-up by pressing specific keys as follows:

- down and right keys erases and initializes the memory.
- down key only eraser the almanac
- right key only erases the ephemeris.

When pressing the "ESC" key as when the main menu is displayed, the software version (and possibly later a hardware option such as rubidium) will be displayed.

```
HAM_31_T 960223.1t
   (no options)
```

While holding down the MENU/ ENTER key the contrast and brightness settings of the LCD will be displayed. Changes are made with the arrow keys (keep holding down the MENU/ENTER key). The LCD backlight is adjustable in three steps. The contrast is adjustable in seven steps, but only the upper four are of practical use. Any changes such as brightness and contrast are directly noticeable.

```
SET  contrast = 5
   backlight = 3
```

Other inputs which will influence the operation of the instrument or the signal output will first be placed in a buffer and are not initially effective. However the "Data Changed" LED will be lit. Changes will be confirmed when pressing the "Enter" key.

If the Data Changed LED will not come on, the MENU/ ENTER key will always return the mode to the main menu and the "Esc" key into that last previous menu for which the call-up was displayed.

However if the main menu is displayed, the "MENU/ ENTER" key will give contrast and brightness and the "Esc" key the version number.

If the "Data Changed" LED remains lit, pressing the "MENU/ ENTER" key will enter the changed and displayed data. Pressing "ESC" will cancel that data and restore the original data. In both cases the LED will not be lit and the menu remains active. The menu will be left by newly pressing the "MENU/ ENTER" or "Esc" keys.

Some menu options are only a demand on the HM 8125 (e.g. in the Use or Track menus) which will be followed only with some delay (e. g. Tracking only SA-free satellites). In case a wrong position is entered the instrument will not follow the instruction to use it. For this, comments or warnings will be displayed.

Lock Lost

If the HM 8125 "assumes" that one of the output signals (DCF77, 1 pps, 10 MHz, 2.048 MHz or 1 kHz) is unsecured (because the internal limit of 50 ns or 50xE-10 frequency errors of the 10 MHz oscillator is reached) then the Lock Lost LED will blink. This is also the case when the equipment is first installed or if during normal operation and through unfavorable "sight" (e.g. Atmospheric Disturbances) a satellite is lost.

The blinking of Lock Lost does not automatically mean that the frequencies are no longer generated; instead it means that the normal precision of the generated frequencies may be impaired. In general, this is a short-term condition and the receiver will return to normal operation shortly.

If the synchronization is lost, the Lock Lost LED will continue to blink and must be canceled by pushing the

ACKN key. Thereby a notice of a “Lost Satellite” will appear even with a successful synchronization. In parallel with the LED is a relay contact which can be used to indicate any “lock lost” state. The relay contact is open when the HM 8125 is correctly coupled with a satellite signal. If synchronization is lost, even for transient conditions, the relay contact will close. However, different from the LED, no report will be given from the relays when the correct reception is re-established.

The last event that was important for the lock condition before it was lost will be displayed in the upper line when the “ACKN” key is held in. This may (but must not be) the condition which may have led to the lost lock. The actual lock condition is displayed in the lower line. The old condition will be displayed when the “ACKN” key is released.

Various over-range conditions in the receiver, which are discovered during the internal self-test, will give a displayed warning with abbreviated text. These warnings can be erased by the “ESC” key.

Pressing any other key will not do the erase the notes. After the “ESC” key is pressed, the display that existed before the warning will be re-established.

Menu Structure

Main-Menu	Sub-Menus			
TIME	LOCAL	DST	UTC	1PPS
FREQ	QLTY	MEAS		
RECVR	TRACK	USE	POS	
STAT	ORBIT	ACC	LIST	LOCK

The following is the main- and sub-menu structure for HM 8125 operation. The sub-menus are available via the cursor keys. The cancellation of a sub-menu is made by pressing the “ESC” key. In most sub-menus, inputs and changes are possible.

Sub-Menu Description

TIME

```
        TIME:
LOCAL DST  UTC  1PPS
```

LOCAL

Date (JMD)   Time (hr/min/sec)
MJD Wtg Zone S   <- DST Indicator

MJD = Modified Julian calendar is by definition always in UTC.
All other inputs describe the local time which can be (UTC +offset) or also GPS time.

```
1996-JUN-11 07:06
50254  TUE  UTC-2h S
```

When no satellite has been received (noticeable though absence of seconds) this condition is an editor for entering the local time. The receiver will re-construct the GPS-Time from this and the time zone. After the receiver has defined the time (from the first satellite and recognizable from the running seconds) only the time zone can be changed for which the local time will be indicated. The internally used GPS-Time can not be influenced. MJD, weekday and daylight savings time can not be entered since they will be derived from the other data.

> ***IMPORTANT!***
> ***Changes of the actual time zone in LOCAL (The time zone will be interpreted as summer (ST) or winter time zone ST -1 hour.) will also influence the DST.***

DST (Daylight SavingTime)

```
UTC-2h: last Sun Mar
  until Last Sun Sep
```

Daylight Saving Time is selectable freely at the beginning and end. It calls out the weekends at which DST begins and ends. It displays also the offset of the DST to the UTC. The wintertime offset is always DST minus 1 hour. Exceptions are as follows: If the beginning and ending weekends are the same, no changeover will be executed and the shown DST time zone is used. If the GPS time is used in place of the DST time zone, the summer and winter time zones are not differentiated.

> ***IMPORTANT!***
> ***Changes in DST can also change the time zone used in LOCAL (dependent upon the date) and the time transferred with the DCF77 timing.***

UTC

```
UTC=GPS-(11s + 49ns)
             + 2ns/d
```

UTC = GPS - [(LS + Distance) + Rate]

The display will show the relation of GPS-Time <->UTC (USNO) .
Where:
LS = Number of Switching seconds (Leap-Seconds)
Distance = Distance between second marks (GPS) and second marks (UTC)
Rate = Time-dependent change of the position: 1 ns/d (approximately 1E-14)

If there are unknown parameters, (?) will be displayed. If the data source is the buffer memory, "old data" will be displayed along with the satelite information.

1 PPS

```
1PPS:  UTC delayed
   by 000000000 ns
```

[Scale + Delay]

Scale can be UTC or GPS which will be nearly the same and different only by a few ns as indicated in UTC. Without a rubidium oscillator these changes will hardly be noticeable. The 1 pps pulse available at the output may be shifted within ± 0.5 s to the displayed scale. The resolution is 1 ns. Any changes will cause in general a "Lock-Lost" since the reference oscillator must be "shifted" to the new phase or as a minimum the 1 pps-divider must be newly synchronized. This will be indicated in the upper line of the display.

```
     FREQUENCY:
QLTY MEAS
```

FREQ

```
QLTY: δt=      ? ns
     δf/f=     ? E-10
```

QLTY

δt = ...ns
δf = ...E-10

The lack of the 10 MHz regulation will be indicated. This will be the result of a deviation of the time and frequency from the (SA-disturbed) apparent GPS or UTC time.

```
MEAS:       gate= 2s
   -- unlocked --
```

MEAS

[gate = ..10 MHz + ...ppm]

The resolution is selectable either as Gate-Time (1x10E9 or 1x10E10) or as the presentation for the measurement (in MHz or as deviation from 10 MHz, in ppm or ppb). The measurement range is 10 MHz ± 70 ppm (approximately ± 700 Hz).

An extra report will be given on the lower line when the 10 MHz is not locked or if the input signal is missing.

RECVR

```
     RECEIVER:
TRACK  USE  POS
```

TRACK

```
TRACK all in view: 8
chang'd:0/8 sats used
```

```
TRACK all w/o view:  0
chang'd:0/8 sats used
```

This sub-menu selects whether all satellites or only satellites without S/A should be tracked. The selection is made via the "up/down" keys and confirmed by "Enter".

All in view = gives all "visible" satellites (automatically tracked when the HM 8125 is powered up).

All w/o SA = gives all SA-free satellites (SA-Selective Availability)

In the lower display line it will be indicated how many satellites are tracked of those which are expected taken time and place data into account.

USE

```
USE entered position
 (not yet verified!)
```

This sub-menu mode is initialized with "initial" position or "averaged" position when switched on.

"USE" permits the selection of the location-variable to be used. From these coordinates the initial-predictions are calculated. Corrections are applied to these coordinates which will lead to the averaged position. If a wrong location is entered (e. g. an error occurred during entry or an earlier leftover "initial" position remains) it is refused with a warning and the HM 8125 uses the location which is known to the HM 8125 as the most reliable.

POS

```
entered:50°05.297'N
 0118m  008°38.813'E
```

This sub-menu gives the position of the place where the instrument is under operation, in terms of latitude, longitude and height above geoid (mean sea level). The selection whether entered, initial, or averaged position is to be used is done in the sub-menu "USE".

At the start, all variables will be initialized with the last location that was used before and independent of which mode that was (initial, entered, averaged).

Only the "entered" position can be changed in this sub-menu. If no location was calculated, changes are also transmitted to the "averaged" position. Updating of the "averaged" position will work independent of its use. The starting point for calculations is always the location specified in "USE". The calculations are a prediction of the expected measurement results and calculations of corrections for deviations from actual measurement results.

STAT

```
      STATUS:
ORBIT ACC LIST LOCK
```

ORBIT

```
Sat01 E1= 1° Az=225°
    3 SN= ?  URA= ?
```

The Display shows:
The Number of satellite and the elevation, the azimuth, the noise power ant at the least the **SNR** (Signal- to Noise Ratio) and **URA** (User Range Accary)

ACC

```
ACC: SA=off,0/6 sats
        POS=entered
```

This sub-menu gives notice about the locked satellites in terms of SA, number of satellites and their location.

LIST

```
LIST: 0220312-2----0
  001000202112000-0-
```

This listing of all available satellites shows for each satellite one character which is interpreted as ASCII-Hex with 4 Bits as follows:

LSBIT = Bit0 = 1: Satellite is O. K. and over the horizon. Elevation >10° (below 10° will be masked)
Bit 1 = Tracking data known
Bit 2 = All information known for Direct Lock (tracing)
Bit 3 = Satellite is locked (traced)
Blank: No new information; new data are actually read

LOCK

```
LOCK: 10.00=?? (int)
 10.23=??  2.048=??
```

This sub-menu provides a rapid overview of the condition of the different internally coupled control circuits. The message "10.00 bad" and/or "10.23 bad" means that there are problems with the GPS receiver. However, the message 2.048 bad closes the relay and the LED blinks, but does not in general disturb the GPS-locked operation.

RS-232 Interface

The HM 8125 has a built-in RS232-serial interface to provide permanent control of the "lock"-status of the HM 8125. The hardware output is a 9-pin female, D-Sub connector. The connection to the controlling computer is made via a standard RS-232 cable (RX/TX/RTS/CTS 1:1 connected).The serial interface will send every 30 minutes and at every Lock status change the information about time and accuracy of the HM8125 internal oscillators.

The serial interface is controlled by a software which is supplied with the HM 8125. To install the software to your harddisk simply copy the files to a separate directory and start the software by **"GPS_PRO2.EXE"**. The default data rate is set to 9,600 baud. This rate can be changed internal to the HM 8125 by a plug arrangement. The COM-port which is used must be selected and a file name should be given, which later contains the measured data. The captured information can be read by a word processor.

The software provides the following information:

$PUTC,96-03-08,12:11:04,1,+5E-10,-6E-10,+1E-10,+1ns,-1ns,+0ns

$PUTC indicates that the given time is UTC, which does not comply with the local time in most cases. After date and time a single digit code (0,1, 2,) indicates whether the instrument is locked (1), unlocked (0), or the 10Mhz oscillator is locked but another internal oscillator is not locked (2) during transmission of the information. Transmission is on power-on every few minutes until the HM8125 is locked. In the locked status transmission is every 30minutes, except when a lock-lost occurs. In that case the unit immediately transfers the respective data. Accuracy information is as follows:

+5E-10 Max. positive frequency deviation during 30minutes
-6E-10 Max. negative frequency deviation during 30minutes
1E-10 Variance of frequency deviation during 30minutes
+1ns Max. positive timing deviation during 30minutes

-1ns	Max. negative timing deviation during 30minutes
0ns	Variance of timing deviation during 30minutes

Complementing information to the data used in the menus Buffered Data

Data which are stored in the buffered RAM and which are active by (again) turning on the HM 8125, can be erased (or set to default values) by holding the "down" and "right" keys while switching on the HM 8125.

SET:	Contrast and Brightness
LOCAL:	Time, Date and Time Zone
DST:	Time Zone, First and Last Day
1 PPS:	Delay and Time-Scale (GPS or UTC)
UTC:	Number of Switching-Seconds, and clock delay and deviation
MEAS:	Gate-Time and display
USE/POS:	Coordinates of the last used location

Data which is initialized when the power is turned on, (in)dependent from earlier settings:

LOCAL:	Date and Time are derived from the running clock
TRACK:	"All in View" to search or track
POS/USE:	All variables are obtained from the buffered memory, coordinates are initialized.

The HM8125 will automatically renew the following:

- The list of the available satellites, SA-activation
- The tracking data (Coarse - Almanac, Fine - Ephemeris)
- The relation UTC <->GPS (Switching-Seconds, Clock Delay/Clock deviation)
- The updated and averaged POS: Length, Width, Height, accuracy of the internal 10.23 Mhz osc.

Error messages

The error messages can only be reset (acknowledged) by pressing the ESC key.

```
WARNING: noise low →
 check antenna cable
```

```
WARNING: can't find
      any satellites
```

```
position changed:
 for a 1st satellite
```

Buffered data is lost:	Will be newly generated
Noise low - check antenna cable:	Is antenna and cable connected? Too big an offset on ADC
Cannot find satellite:	Dependent on Local and POS/USE
Cannot find sufficient number of satellites:	Dependent on POS/USE
Xtal offset too big:	Possible location is unknown
Xtal offset too big:	If location is known, desired location is not plausible
UTC ↔ GPS are too old!:	Leaving the POS editor with changed coordinates

Lock-Lost Reports with "ACKN" Key Depressed

'position changed: searching for a 1st satellite'	Mains position and time unknown
'wait: searching for more satellites' 'pos. found! searching for more satellites'	Means that as a minimum the time is known
'Lock proc. started (re)approaching Lock'	Means that the Lock-Trial has started
'Lock proc. started:' '-- locked --'	After changes in 1PPS
'UTC vs. GPS changed'	After reading relevant Satellite data
'position changed'	After changes in POS/USE
'10.00MHz Lock lost' (re)approaching Lock	For example; Trouth a sudden temporare change
'10MHz Lock lost' '-- locked --'	Oscillator is Lockeed
'2.048MHz Lock lost' (re)approaching Code	Generally the 8.192MHz Oscillator is falsely adjust
'2.048MHz Lock lost' '-- locked --'	Oscillator is Locked

Notes for the DCF77-Code

The DCF77 second-marks (occurring at the pulse decay) are the same accuracy as the 1pps, meaning as in the SAT-Mix, typical ± 50ns. The pulse duration of nominal 100 ms or 200ms is not that precise. The accuracy is within ± 550µs. The second-marks can be delayed in their timing the same a the 1 pps by the selection of the delay in the sub-menu PPS. The duration of the DCF-pulse (100 or 200ms) will be generated at the same time as the UTC-second to which the output second-mark is earlier or delayed. This can mean, when two receivers are used, and one is set to + 0.5 s and the other is set to - 0.5 s will simultaneously generate their 1 PPS- and DCF-second marks but the simultaneously starting DCF-pulses are of different duration.

The receiver with + 0.5 s advance will always issue that pulse duration which the other receiver (with - 0.5 s delay) issued 1 s before. Both codes are really describing the same UTC-second which lies exactly in the middle of the two equal duration pulses. One receiver describes every second with one-half second delay which the other receiver has described one half second before.

Use of GPS Receivers for Frequency andTime Determination

GPS-receivers are much more complex than other timing mark receivers, but in the near future they will be no more expensive than other crystal or rubidium oscillators. The many-sided usability of the GPS-receivers will in the future permit a large scale production of the GPS- receiver circuitry. It must be noted that the differences between receiver concepts are important. This is especially so for the advantages of carrier-phase measurements for fast recognition and control of frequency variations which is used in the HM 8125. The accuracy can be demonstrated on the basis of measurements for the different techniques employed. For this, the use of only one receiver as well as differential methods (DGPS) are considered.

Functional Principles of the GPS System

The Global Positioning System (GPS) is a satellite-supported navigational system which has besides its primary function of location determination also that of accurate time and frequency determination. The navigational determination is made by measuring the distance of the receiver to different satellites. For this purpose, the delay time of the signals from different satellites are measured. From these signals and by use of the tracking data the location and also the clock delay of the receiver-clock is determined. Correspondingly, from the change in rates of the delay time will also allow the determination of the speed of the receiver and the accuracy of the receiver-clock. The availability of the data necessary for the calculations is the task for several ground-based GPS tracking stations. These tracking stations determine from the delay time measurements the tracking and other data. This data is sent to the satellites which, in return, make these data available for the individual receivers.

The delay time of four different satellites are required for a three-dimensional position determination. Three satellite signals are required for the searched-for location coordinates and one satellite signal is required to determine the (originally unknown) clock delay of the receiver-clock. For a time-only receiver located at a known place, only the reception of one satellite signal is required. However, if several satellite signals are received, the reliability will be increased through consistency tests. Since at least five satellites will be above the horizon, a great redundancy exists for the time determination. In addition, the influence of the Selective Availability (SA) can be reduced by the messages about the measurement results. The delay time measurements are performed by use of a correlation procedure. The carrier signal (1.575 GHz) from the satellite is modulated with a (for each satellite characteristic) pseudo-noise-code of 1023 Bit length and 1 ms duration. The beginning of the code sequence is coincident with the precise milli-second of the satellite clock. At correlation of the received antenna signal and a similar code generated in the receiver one can determine the code-phase of the signal at the antenna at the 1 ms mark. The remaining inaccuracy of the number of milli-seconds delay time is removed by the evaluation of the 50 Baud data stream.

Obtainable Accuracy of Straight C/A -Code Receivers

The correlation function is a triangle with a width of 1 µs. Outside of this triangle the correlation signal can not be found. With a typical signal-to-noise ratio the middle of the triangle can be resolved to 10 ns in 1 s (1 % of the width). Figure 1 shows a measurement series (dotted curve) which is the difference between the delay time expected from the satellite tracking data and that measured by the receiver. This difference is the value which the receiver calculated for the clock delay of its clock as compared to the GPS system time. Factually, the receiver clock was synchronized to an atomic clock which made the clock deviation originally zero. This delay was increased to a defined value of 12x10E-9. Subsequently, the delay steadily increased until the clock deviation was set back in approximately 20 s.

For a frequency determination, an accuracy of 10E-8 is thereby reached from two sequential independent measurements of the code-phase with 1 s separation. This is the same accuracy that a straight C/A-code receiver can regulate an oscillator rated frequency in 1 s.

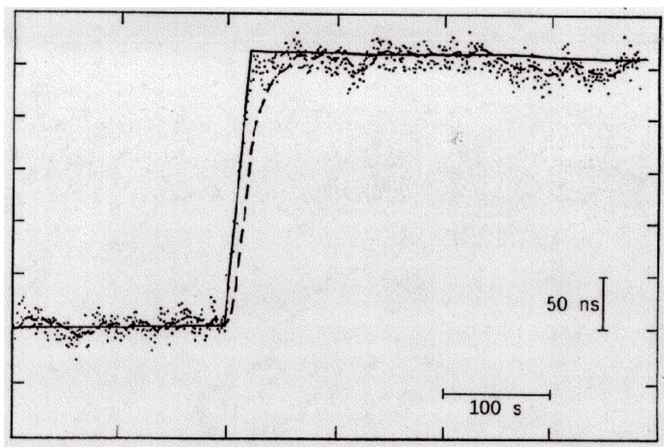


Figure 1 Measured Clock Delay of the Receiver Clock as Compared to the GPS-Clock
C/A-Code ····; Code Transmitted ---;
with Carrier-Phase ——

Since the obtainable accuracy is limited by the signal to noise ratio, the accuracy will be increased by averaging over several measurements. The result of averaging of the clock delay over 10 s is shown in Figure 1 as the dashed curve. The disadvantage of averaging is that sudden changes in the signal condition can only be noticed at the end of the averaging period. This effect is especially noticeable in Figure 2 which shows the deviation of the averaged clock delay, which means the measured clock deviation is shown.

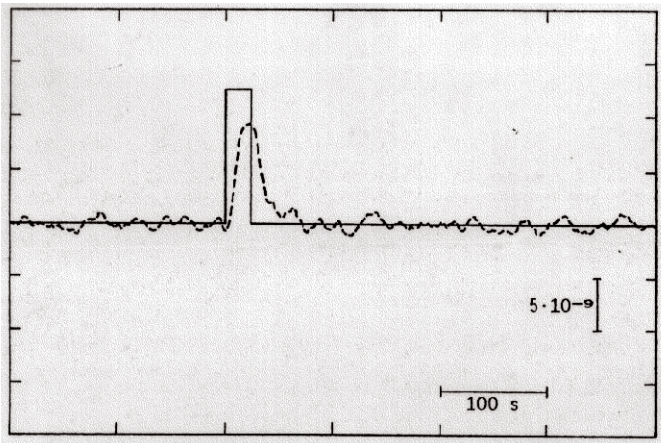


Figure 2 Measured Clock deviation of the Receiver Clock as Compared to the GPS-Clock Code Averaged ---; With Carrier-Phase ——

The curve in Figure 2 shows the response of a straight C/A-code receiver to a frequency jump.

Instead of the sudden jump, the receiver records a slowly increasing frequency which because of the short duration of the frequency jump is already decreasing before the true value is recorded. With such a GPS receiver one can only "discipline" an oscillator which already has a good stability.

Obtainable Accuracy for Receivers with Carrier-Phase Measurements

The same as with DCF77, the measurement accuracy of a GPS receiver can be significantly improved by not only measuring the modulated code but also carrier-phase. Because of the high frequency of the carrier a very low sensitivity of the phase-time measurements results as compared to noise and disturbing signals. With a period-duration of 635ps (as compared to the width of the correlation peak of 1µs) the resolution is theoretically increased by a factor of 10,000, as compared to the C/A-code, with the same measurement time.

Figure 3 shows schematically the difference of both measurement methods. The correlation triangle (heavy line) has a rise of 1/µs. A displacement of the signal caused by noise of (e. g.) 1% of the amplitude will cause to an apparent displacement of the code-phase of 10 ns. The correlation function of the carrier, which is the sinusoid enclosed by the triangle, obtains a rise of 2 µ/period-duration÷10000/µs (in place of the 1,540 periods at one µs only 8 are shown). Consequently the same change of the signal will lead to an apparent displacement of the carrier-phase of only 1ps.

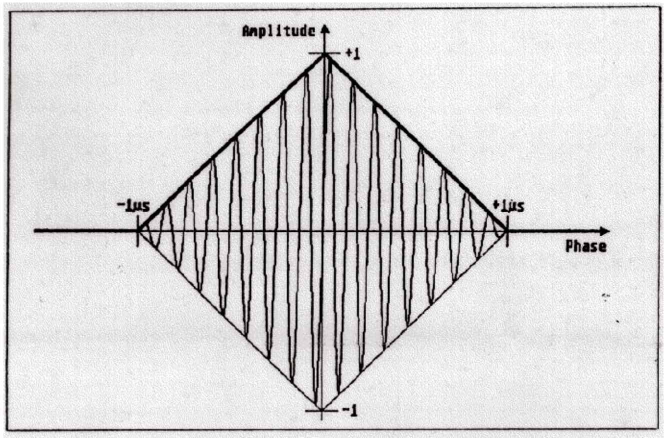


Figure 3 Schematic Explanation of Code- and Carrier-Correlation

The significantly higher rise of the carrier-phase curve enables practically error-free frequency measurements within very short periods. Therefore, a GPS receiver can measure within a fraction of a second, the frequency with a relative accuracy of 10E-11. In Figure 2, the solid line shows the clock deviation of the receiver clock that was won from the carrier-phase measurements. This curve reproduces in a practically ideal way the frequency jump previously mentioned.

Combined Utilization of CODE- and Carrier-Phase

Measurements of the carrier-phase alone are not suitable to determine the delay time of the signals since the different periods of the carrier are not differentiated. To determine the delay time, the modulated code must be used. An exception to this are specific differential procedures that are used for geodetic receivers. From measurements of the carrier-phase, the change in the delay time can be determined very accurately. Once the delay time has been found updates are possible by integration of the carrier phase.

A suitable combination of code- and carrier-phase measurements unifies the (noisy) absolute-information of the C/A code with the significantly more accurate relative-information from the carrier-phase advance. Practically, this means that by the common evaluation of the code- and carrier-phase the delay times are smoothed without suffering any time lag.

Figure 1 shows in the solid line the time delay of the receiver clock as determined by the combined measurement procedure. The noise is in comparison to the code measurement only (dotted line) negligible. At the same time neither rounding nor delay occurs which would be normal for averaging the data to reduce the noise (dashed line).

The precision of a measurement- or transmission procedure can be characterized, similar to the stability of an oscillator, in accordance with the Allan - Variance. Figure 4 also shows the frequency stability as a function of the averaging time for somewhat different relationships (Signal/Noise Ratio, S/N, and duration of the individual measurement).

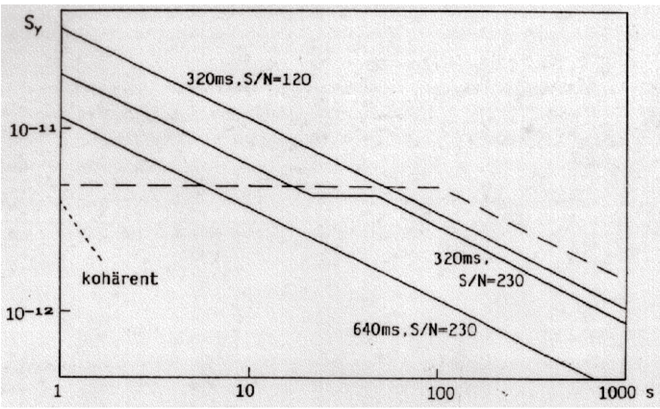


Figure 4 Short-Duration Stability (Standard Deviation) of Different Carrier Frequency Measurements Specification of a Cesium Atomic Clock — Expected Measurement Resolution With Coherent Evaluation ····

In fact, once per second the receiver will perform independent carrier frequency measurements with an observation time between 80ms and 640ms. These measurement results can then be averaged. The curves fall off at a rate of -1/2 and in accordance with that, the limiting effect is noise and not a systematic error. With this non-optimized (dead-time encumbered) evaluation of the carrier signal, the receiver can measure several satellites quasi-simultaneous and evaluate in parallel

The attainable short-duration stability at optimum evaluation is shown in Figure 4 as "coherent" and by the dotted line. As a comparison, a Cesium Atomic Clock is also shown as a dashed line. These curves show that a carrier-phase generator/GPS-receiver cannot only "discipline" an atomic clock but also replace it. This high accuracy can not be obtained from a straight C/A-code receiver even with (the now customary) several parallel circuits. For a receiver which can measure the carrier-phase it is sufficient to follow the satellites in time-multiplex with only one channel.

Limits for the Usable Accuracy

The operators of the GPS system are artificially making the signals and data worse for civilian use.

Therefore the high accuracy in the signal evaluation and absolute accuracy is possible only with a few classified satellites. Apparently the satellite clocks are delay modulated. Possibly, small errors may also be included in the tracking data. These errors which are introduced for the purpose of "Selective Availability" (SA) lead to an error of 100 ns in the clock delay measurement and an error of 10E-9 for the clock deviation measurement.

An elimination of these errors is only possible by knowing the classified procedures.

Which one of the satellites is disturbed by the activation of the SA function is impossible to predict.

Even though the activation of SA is recognizable from the tracking data. Only four of the total of 24 satellites are from the previous generation during which modulation of the clock deviation was not available. Consequently, they deliver measurement values with higher accuracy. The data shown in Figures 1, 2 and 4 was obtained from non-disturbed satellites.

Another source of inaccuracy is the influence of the ionosphere on the signal spreading. Even though two models exist for diminishing these errors, their application can not totally eliminate these errors.

Differential Measurements (DGPS)

Neither the errors generated by SA nor the errors generated by the ionosphere can be eliminated in the receiver. If higher accuracy for the time and/or the frequency measurements is necessary, a differential operation is used. The following describes this procedure. The receiver is connected to an atomic clock and at a known location. It then measures the momentary clock-errors of all "visible" satellites. GPS receivers which will receive these measurement results via radio or telephone can then utilize this data in the evaluation and apply a correction factor. The differential procedure will eliminate all errors which are the same at the location of the reference-receiver and the location of the GPS receiver. The distribution of the correction data could be a service of the same organization which presently broadcasts timing signals.

The valuable use of such a service was demonstrated by the German PTB (Physikalisch Technisches Bundesamt). An experiment was performed with two receivers. Figure 5 shows the measurements of two independent receiver measuring a satellite with active SA. The two outside curves show the clock-delay times which clearly show the effect of SA. The curve in the middle shows (enlarged for clarity) the difference between the code-phase measurements of both receivers. The remaining error is significant; however, it is smaller than of each receiver. It is also recognizable that the error is not caused by white noise.

It is assumed that the remaining error was caused by local reflections which may have been different for each antenna location. By careful selection of the antenna location these errors can be eliminated.

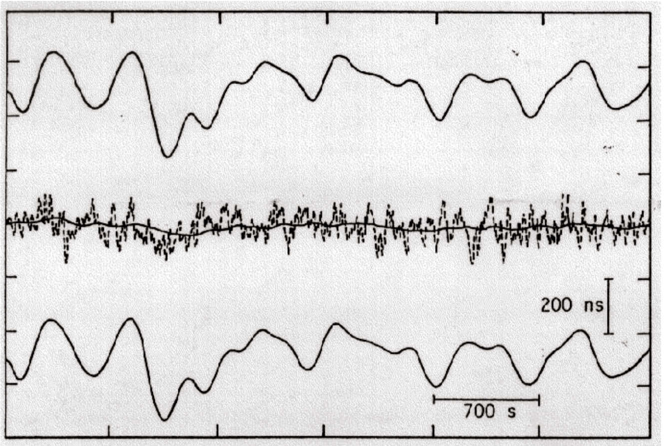


Figure 5 Clock Delay of Two Independent Receivers is Shown in the Upper and Lower Curve, The Middle Curve Shows the Difference of the Delays (4 Times Enlarged) Code Averaging ---; With Carrier-Phase ——

If the carrier-phase measurements are also used, the differences will be much smaller since the reflection errors (the same as the noise) have less influence on the carrier-phase measurements than on the code-phase measurements. For the predominant portion of the measurement time, the remaining error is smaller than 3 ns with the largest error at 10 ns. Consequently, this also shows the advantage of the combined code- and carrier-phase measurements which deliver high accuracy within a very short measurement time high accuracy.

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Bei Datenleitungen ist generell auf doppelt abgeschirmtes Verbindungskabel zu achten. Als IEEE-Bus Kabel sind die von HAMEG beziehbaren doppelt geschirmten Kabel HZ72S bzw. HZ72L geeignet.

2. Signalleitungen
Meßleitungen zur Signalübertragung zwischen Meßstelle und Meßgerät sollten generell so kurz wie möglich gehalten werden. Falls keine geringere Länge vorgeschrieben ist, dürfen Signalleitungen eine Länge von 3 Metern nicht erreichen.
Alle Signalleitungen sind grundsätzlich als abgeschirmte Leitungen (Koaxialkabel -RG58/U) zu verwenden. Für eine korrekte Masseverbindung muß Sorge getragen werden. Bei Signalgeneratoren müssen doppelt abgeschirmte Koaxialkabel (RG223/U, RG214/U) verwendet werden.

3. Auswirkungen auf die Meßgeräte
Beim Vorliegen starker hochfrequenter elektrischer oder magnetischer Felder kann es trotz sorgfältigen Meßaufbaues über die angeschlossenen Meßkabel zu Einspeisung unerwünschter Signalteile in das Meßgerät kommen. Dies führt bei HAMEG Meßgeräten nicht zu einer Zerstörung oder Außerbetriebsetzung des Meßgerätes.

Geringfügige Abweichungen des Meßwertes über die vorgegebenen Spezifikationen hinaus können durch die äußeren Umstände in Einzelfällen jedoch auftreten.

Dezember 1995
HAMEG GmbH

General information regarding the CE marking

HAMEG instruments fulfill the regulations of the EMC directive. The conformity test made by HAMEG is based on the actual generic- and product standards. In cases where different limit values are applicable, HAMEG applies the severer standard. For emission the limits for residential, commercial and light industry are applied. Regarding the immunity (susceptibility) the limits for industrial environment have been used.

The measuring- and data lines of the instrument have much influence on emmission and immunity and therefore on meeting the acceptance limits. For different applications the lines and/or cables used may be different. For measurement operation the following hints and conditions regarding emission and immunity should be observed:

1. Data cables
For the connection between instruments resp. their interfaces and external devices, (computer, printer etc.) sufficiently screened cables must be used. Without a special instruction in the manual for a reduced cable length, the maximum cable length of a dataline must be less than 3 meters long. If an interface has several connectors only one connector must have a connection to a cable.

Basically interconnections must have a double screening. For IEEE-bus purposes the double screened cables HZ72S and HZ72L from HAMEG are suitable.

2. Signal cables
Basically test leads for signal interconnection between test point and instrument should be as short as possible. Without instruction in the manual for a shorter length, signal lines must be less than 3 meters long.

Signal lines must screened (coaxial cable - RG58/U). A proper ground connection is required. In combination with signal generators double screened cables (RG223/U, RG214/U) must be used.

3. Influence on measuring instruments.
Under the presence of strong high frequency electric or magnetic fields, even with careful setup of the measuring equipment an influence of such signals is unavoidable.

This will not cause damage or put the instrument out of operation. Small deviations of the measuring value (reading) exceeding the instruments specifications may result from such conditions in individual cases.

December 1995
HAMEG GmbH