Radio Frequency Interference Measurement Plan in the frame of BRAND-EVN project

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1 Introduction

The University of Alcalá de Henares (UAH) and the Spanish National Geographic Institute (IGN) are contributing to the BRAND-EVN work package of the RadioNet project funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730562.

BRAND-EVN work package will develop a prototype broad-band receiver in the range 1.5 - 15.5 GHz for the European VLBI Network (EVN) of radio telescopes. This prototype is to be installed in the prime focus of the 100 meter Effelsberg radio telescope.

As this frequency range is populated with several telecommunication services and the receiver will be very sensitive, there is a risk of receiver saturation, intermodulation generation, and even cryogenic low noise amplifier (LNA) damage due to the reception of interference signals. All these risks can make the receiver useless.

As a result, one of the very first tasks of the BRAND-EVN work package is to perform a measurement of the radio frequency interference (RFI) environment in those observatories with strong interest in such a broad-band receiver. The analysis of these measurements will allow the definition of a RFI mitigation approach as, for example, high temperature superconducting (HTS) filters in front of the LNAs.

This report describes the plan envisaged for the measurement of the radio frequency interference signals at Yebes (Spain), Effelsberg (Germany) and Westerbork (Netherlands) observatories, with the instrumentation available at *Centro Astronómico de Yebes* (Spain), in the frame of the BRAND-EVN project.

Other EVN observatories in the frame of the BRAN-EVN project, willing to perform the RFI measurements on their own, will be teached on how to use the RFI instrumentation, which can be borrowed from Yebes Observatory at no cost other than transportation from and to Yebes.

Firstly, the instrumentation used for this purpose will be introduced. Secondly, the equations relating the power spectrum measurements with the incident electric field intensity of RFI signals in the measurement site will be given. After this, the measurement setup and data acquisition process will be described.

2 RFI instrumentation

The instrumentation used for the RFI measurements consists of the following elements:

- Wideband 0.9 meter parabolic antenna AC008 from Rohde-Schwarz (see appendix A for details).
- Wideband 1 - 18 GHz crossed log-periodic antenna HL024S5 from Rohde-Schwarz (see appendix B for details), which works as the feed of the AC008 parabola.
- Control unit (GB016S5) for HL024S5 feed, which is used for controlling the polarization network, internal low noise preamplifiers and bypass switch of the HL024S5 feed (see appendix C for details).
- Prosistel PST2051 antenna rotator for the automatic rotation of AC008 antenna in azimuth.
- Prosistel control unit 'D' for antenna rotator.
- Tripod to mount the rotator plus the AC008 antenna.
- DC - 20 GHz Keysight N9344C spectrum analyzer (see appendix D for details).
- Laptop for data acquisition from the analyzer.
- Low-loss coaxial cables.

Figure 1 shows the deployment of the RFI system during the measurements on the roof of the laboratory building at Yebes Observatory. At the moment of the picture, the rotator was not integrated.

The ensemble AC008 antenna plus HL024S5 feed receives signals in the 1 - 18 GHz frequency range. The antenna can be turned $\pm 360°$ in azimuth and tilted from $-6°$ to $+44°$ in elevation.

The HL024S5 is an active feed as it has switchable low-noise preamplifiers in the bands 2 - 4 GHz, 4 - 8 GHz, 8 - 12 GHz and 12 - 18 GHz, as described in table 1 and appendix B. The desired amplifier is selected manually by the switches in the front panel of the GB016S5 control unit, when the control cable between feed and control unit is connected, and hence the sensitivity of the spectrum analyzer is improved[1].

The RF output of the feed (SMA-female) is connected to the low-loss coaxial cable, whose length is 2 meter approximately, to transport the signal up to the spectrum analyzer input. The analyzer can be directly connected to the laptop through an ethernet/LAN cable for data acquisition.

[1]Currently, the measurement noise floor is 25 $dB(\mu V/m)$, approximately.

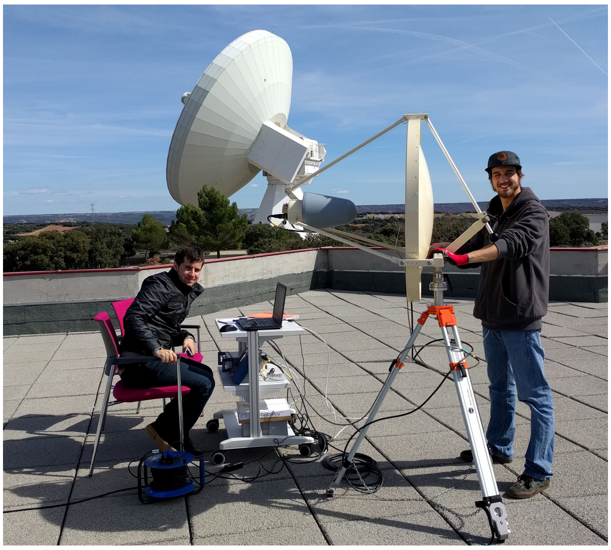


Figure 1: RFI measurement setup.

Parameter	**2-4 GHz**	**4-8 GHz**	**8-12 GHz**	**12-18GHz**
Gain (dB)	26	30	33	38
Gain response (± dB)	2	2	2	2
Noise Figure (dB, max.)	2.5	3.5	4	4.5
Po1dB (dBm, min.)	+15	+15	+15	+15
Max. input power (dBm)	30	27	27	27
VSWR (max)	2	2	2	2
DC supply at +15Vdc (mA)	200	300	300	300

Table 1: Active feed preamplifiers.

All the AC power plugs (laptop, GB016S5, rotator control unit and spectrum analyzer) are connected to a common 50 meter socket extension included in the wooden box that contains all the instrumentation. This box will be shipped to each measurement location.

3 Conversion formulas

In order to convert the power spectrum, measured by the analyzer, to incident electric field intensity on the measurement site, the antenna factor was computed from the antenna gain data and the gain of the set preamplifiers plus low-loss cables from the antenna to the spectrum analyzer.

It can be shown that the incident electric field on the antenna is given

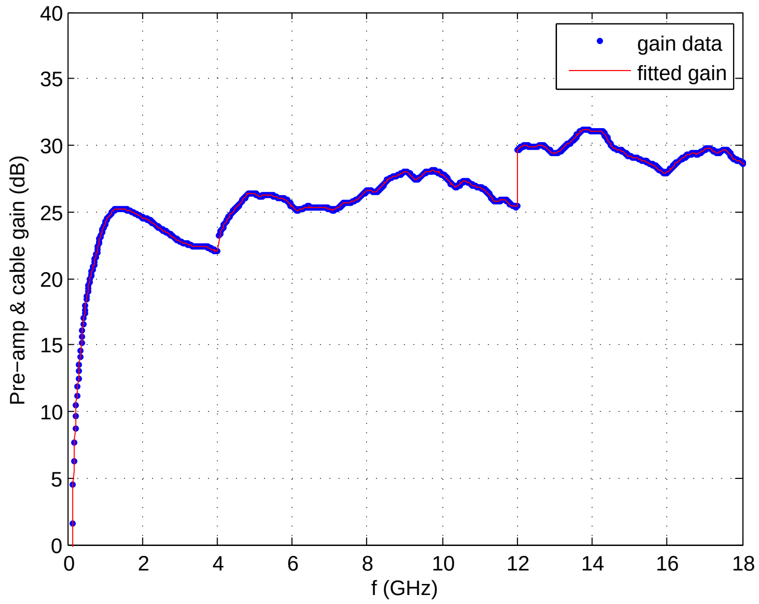


Figure 2: Measured and fitted gain of the preamplifiers plus low-loss cables from the antenna to the spectrum analyzer.

by:

$$E[dB(\mu V/m)] = AF[dB(1/m)] + V[dB(\mu V)] \tag{1}$$

where E is the incident electric field, AF is the antenna factor and V is the voltage measured across antenna terminals.

The voltage V, can be expressed as:

$$V[dB(\mu V)] = 107dB + P[dBm] = 107dB + P_m[dBm] - G_{amp}[dB] \tag{2}$$

where P_m is the power measured by the analyzer at its input port and G_{amp} is the gain of the chain preamplifier plus low-loss coaxial cables from the antenna to the analyzer. This gain was measured in the lab with the help of a vector network analyzer (Keysight N5227A); the measurement was fitted in order to apply this correction to the spectrum analyzer measurements, as needed in equation (2). The measurement and the fit are shown in figure 2, where the jumps in the curves are due to the selection of a different preamplifier.

At this point, the voltage measured at the antenna terminals can be computed, as given by equation (2). Now, the value of AF has to be computed. In useful units, the antenna factor can be written as:

$$AF[dB(1/m)] = 20 \cdot log(F[MHz]) - G_a[dBi] - 29.77 \tag{3}$$

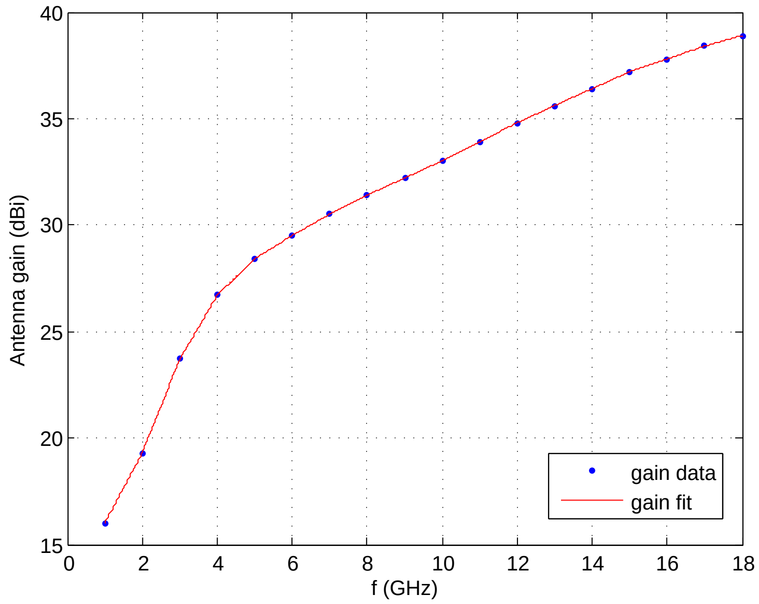


Figure 3: Fitted gain of AC008 antenna.

where F is the frequency in MHz and G_a is the antenna gain.

The antenna gain shown in the last figure of appendix B was fitted in order to have an analytical expression to apply to the measurements. The result is shown in figure 3.

Using this gain fit, the resulting antenna factor is plotted in figure 4 versus frequency, according to equation (3).

Now, all the parameters involved in equations (1) and (2) to get the value of the incident electric field are known, and the conversion from dBm in the spectrum analyzer to $dB(\mu V/m)$ can be performed.

It is clear that some errors are introduced in the computation of E, mainly due to the following sources:

- Errors in antenna gain measurements
- Fluctuations of spectrum analyzer power measurements
- Errors in gain measurements of the preamplifier plus low-loss cable chain.
- Errors in the fitting carried out to compute analytical functions to perform unit conversion.

The value of these errors is difficult to compute. Nevertheless, special care has been taken during the whole measurement and analysis process.

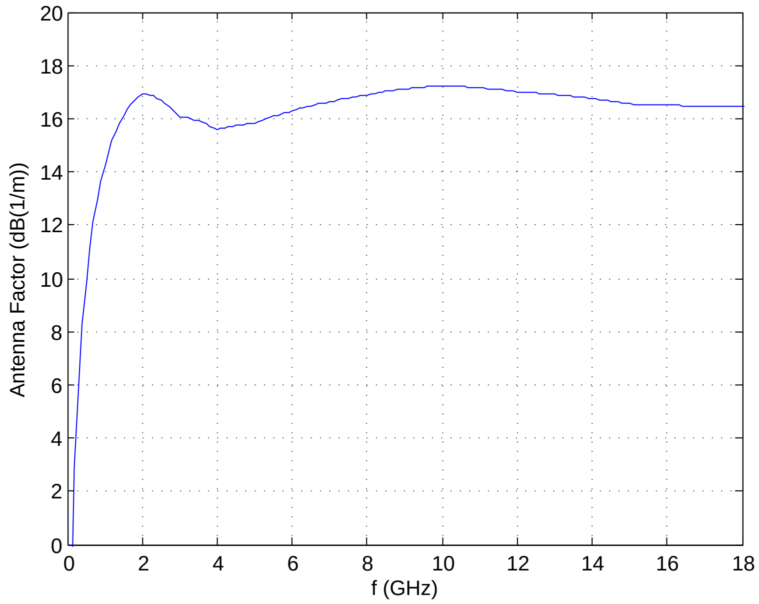


Figure 4: Computed antenna factor.

4 Measurement setup

The RFI instrumentation described in section 2 will reach each observatory packaged in a wooden box. Firstly, the box will be opened and the instrumentation will be transported to the selected measurement place and assembled (mounting the antenna and rotator on the tripod, wiring of the feed, rotator, feed control unit, spectrum analyzer and laptop). A 220V power outlet will be needed to connect the extension socket for AC supply. Alternatively, a genset could be used but it will have to be provided by the observatory where the measurements will be performed.

Secondly, the AC008 antenna will be pointed to the North at 0° elevation to calibrate the azimuth indicator. After this:

1. Run the analyzer control software in the laptop (HSA PC software) and open a connection to the analyzer.
2. Select vertical polarization (V-pol) in the feed control unit.
3. Select first low noise preamplifier in the feed control unit.
4. Use the spectrum analyzer to make a preliminary evaluation of the RFI environment, in order to stablish the suitable parameters for frequency span, amplitude level and resolution and video bandwidths.

5. Once this parameters are selected, set the analyzer in the desired frequency band and set its trace in MAX-HOLD mode.

6. Turn the parabolic antenna by 360° in clockwise direction using the switches in the front panel of the rotator control unit. **Pay attention to the wrapping of the cables around the tripod, it can cause problems!**.

7. Save the analyzer trace with the help of the laptop to a CSV file for data reduction off-line.

8. Select a new frequency band in the analyzer and set its trace in MAX-HOLD mode again.

9. If the current selected band is out of the band of the current preamplifier, then switch to another preamplifier in the selected band.

10. Turn the parabolic antenna by 360° in counterclockwise direction using the switches in the front panel of the rotator control unit.

Each turn represents the integrated RFI along 360° in the selected frequency band. Once the range 1 - 18 GHz is measured, the horizontal polarization (H-pol) will be selected and the mesurement procedure will be repeated.

Detailed power spectra from selected azimuth angles, where the RFI can be important, can be measured too. This will be decided on site.

The measurements will be performed at 0° and 15° of elevation. The 0° elevation provides the worst case scenario in the reception of RFI, while 15° is usually a lower limit for astronomical observations. Other elevation angles could be considered, being 44° the upper limit of the parabola.

The measured spectra will be reduced and analyzed off-line in order to apply the convertion from dBm to $dB(\mu V/m)$, according to the formulas in section 3.

A AC008 parabolic antenna datasheet

ROHDE&SCHWARZ

AC 008

Microwave Directional Antenna AC 008

1 to 18 GHz

Data sheet
N6-352
E-2

MICROWAVE DIRECTIONAL ANTENNA AC 008

The broadband Microwave Directional Antenna AC 008 is used for detecting RF signals and for fieldstrength measurements in the range from 1 to 18 GHz.

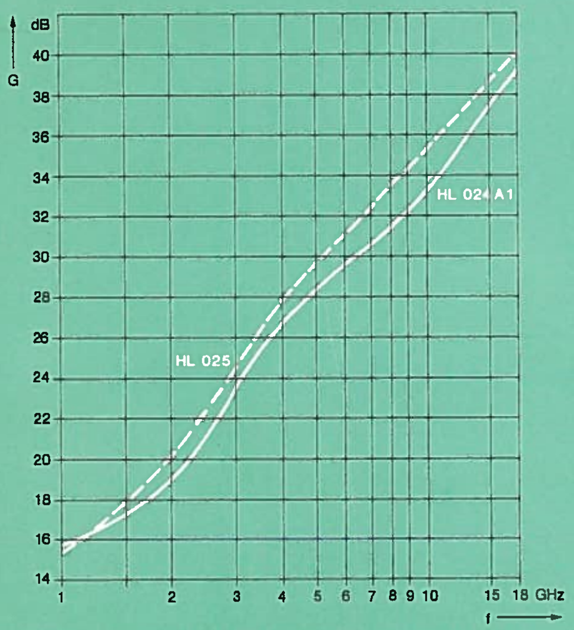
The small dimensions and the light weight of the antenna permit easy transport, troublefree installation in open terrain or on shelters and reliable operation in complex, remote-controlled radiomonitoring systems.

The AC 008 consists of a 90-cm reflector with a broadband feed at the focus and a manually operated biaxial positioning device. The positioning range (unlimited range of rotation in azimuth) allows not only lining up of the antenna on terrestrial targets but also orientation on geostationary satellites from the majority of latitudes. Three different log-periodic antennas are available as feeds, each covering the entire range from 1 to 18 GHz.

On the rear of the reflector, a traverse support with several threaded holes is provided for mounting a platform to accommodate customer equipment. A sighting telescope that can be attached to the side of the reflector enables the antenna to be directed at a known point without tedious searching.

The accessories that are available include a tripod, a sighting telescope, and control and microwave cables. A control unit is offered for the selection of the desired sense of polarization if the AC 008 is fitted with a dual-linear feed and a polarization-switching network. Monoaxial and biaxial rotating devices are available in line with the requirements of the customer.

Feeds	Polarization
HL 025	linear; horizontal, vertical or 45° oblique (depending on position in reflector)
HL 024 A1	dual-linear; horizontal and vertical at the same time
HL 024 A2 (with polarization-switching network)	dual-linear; horizontal, vertical, circular clockwise or counterclockwise (depending on remote selection)



Frequency-dependent gain of AC 008 with Feeds HL 024 A1 and HL 025 (reference: isotropic radiator)

Specifications

Frequency range	1 to 18 GHz
Positioning range	
Azimuth	n x 360°
Elevation	−6° to +44°
Polarization	dependent on feed
Gain	15 to 40 dBi
Half-power beamwidth	20° to 1.5°
Characteristic impedance	50 Ω
VSWR	≤ 2.5
RF connector	SMA female
Dimensions	
Diameter	0.9 m
Depth	0.4 m (folded up for transport)
Weight	12 kg (without tripod)

Ordering information

Order designation	▶ Microwave Directional Antenna AC 008	
AC 008 with dual-linear feed	671.5017.02	
AC 008 with linear feed	671.5017.03	
AC 008 with dual-linear feed and polarization-switching network	671.5017.04	
Feeds (available separately)		
Crossed Log-periodic Antenna HL 024 A1[1]	650.7510.03	
Crossed Log-periodic Antenna HL 024 A2[1] (with polarization-switching network)	677.7063.02	
Log-periodic Antenna HL 025[2]	671.5317.02	
Recommended extras		
Tripod	AC 008-Z	671.5117.02
Sighting Telescope	AC 008 F1	751.6919.02
Control Unit	GB 016 A2	717.0505.02
Control Cable (between HL 024 A2 and GB 016 A2), 5 m long	AC 008 W1	751.6925.02
Microwave Cable (1 to 18 GHz), with two SMA male connectors, 5 m long	AC 008 W2	751.6931.02

[1] see data sheet N6 – 265
[2] see data sheet N6 – 165

Microwave Directional Antenna AC 008 collapsed for transport

Figure 5: Antenna tripod.

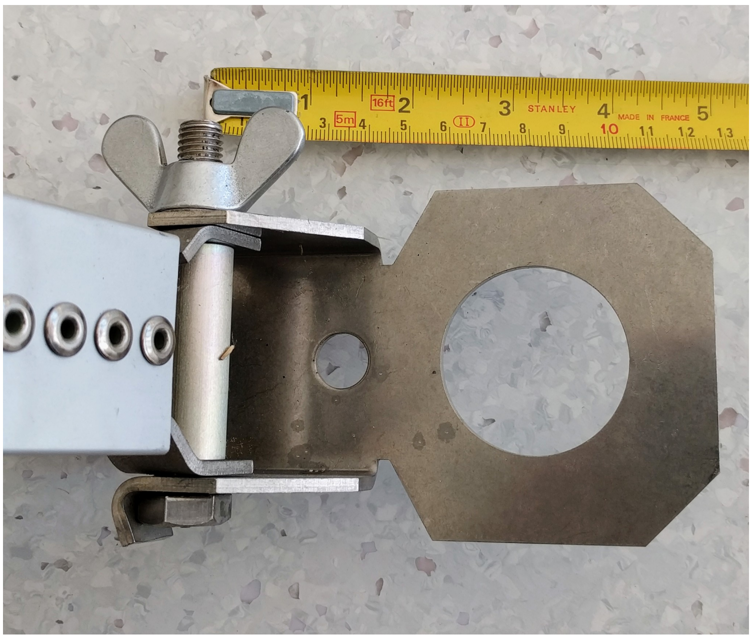


Figure 6: Detailed view of antenna tripod foot.

B HL24S5 feed antenna datasheet

General

Active Antenna Feed HL 024 S5 consists of the Crossed Log-Periodic Antenna HL 024 A1, a polarization switchover network, four low-noise preamplifiers for the bands 2 to 4 GHz, 4 to 8 GHz, 8 to 12 GHz, 12 to 18 GHz and an RF switch for switching between the different bands. The amplifiers can be bridged by activating a bypass. Furthermore, a test signal can be applied for checking the amplifier functions.

This feed may for instance be used with antenna systems AC 090, AC 120, AC 180 and AC 300 for the reception of signals with either horizontal or vertical polarization in the 2 to 18 GHz range. The network in the log-periodic antenna system (see circuit diagram 4047.7507.01 S) either switches the amplifier unit (A1 to A4) to horizontal or vertical polarization (relay K1) of HL 024 A1, or connects it to the test input (relay K2). The bypass or the frequency band desired can then be switched on via the two RF relays K3 and K4.

The amplifiers contain limiters allowing a signal of 27 dBm CW to be fed to the input.

Specifications

Antenna

Frequency range ....2 to 18 GHz (active)
1 to 18 GHz (passive)

Polarization ....horizontal or vertical

Nominal impedance ....50 Ω

VSWR...< 2.5

Gain ....7 dBi

Max. wind speed...180 km/h

Operating temperature range ....-30 to +55 °C

Passive network

Transmission loss ....1.5 to 4 dB

Power supply ....12 VDC/0.75 A

Amplifier

Frequency band [GHz]	2 to 4	4 to 8	8 to 12	12 to 18
Gain [dB]	26	30	33	38
Gain response [± dB]	2	2	2	2
Noise figure [dB, max.]	2.5	3.5	4.0	4.5
1-dB compr. point at output [dBm, min.]	+15	+15	+15	+15
Input power [dBm, max.]	30	27	27	27
VSWR on/off [max.]	2.0	2.0	2.0	2.0
Power supply 15 VDC	0.2 A	0.3 A	0.3 A	0.3 A

Connectors

X1 (RF output) .... SMA socket

X2 (BITE input) .... SMA socket

X10 (Control line) .... 10 pole, PT07A12-10P

Type Designation

HL024 S5 .... 4047.7507.02

Service Information

To guarantee sufficient dissipation of the heat given off by the amplifiers, the amplifiers and all internal metallic interfaces to the base are coated with a heat-conducting paste. If the amplifiers are removed for repair or replaced by new ones, the paste is to be applied again during installation to protect the amplifiers from excessive heat and thus damage (see drawing 4047.7571.01 sheets 1 to 6).

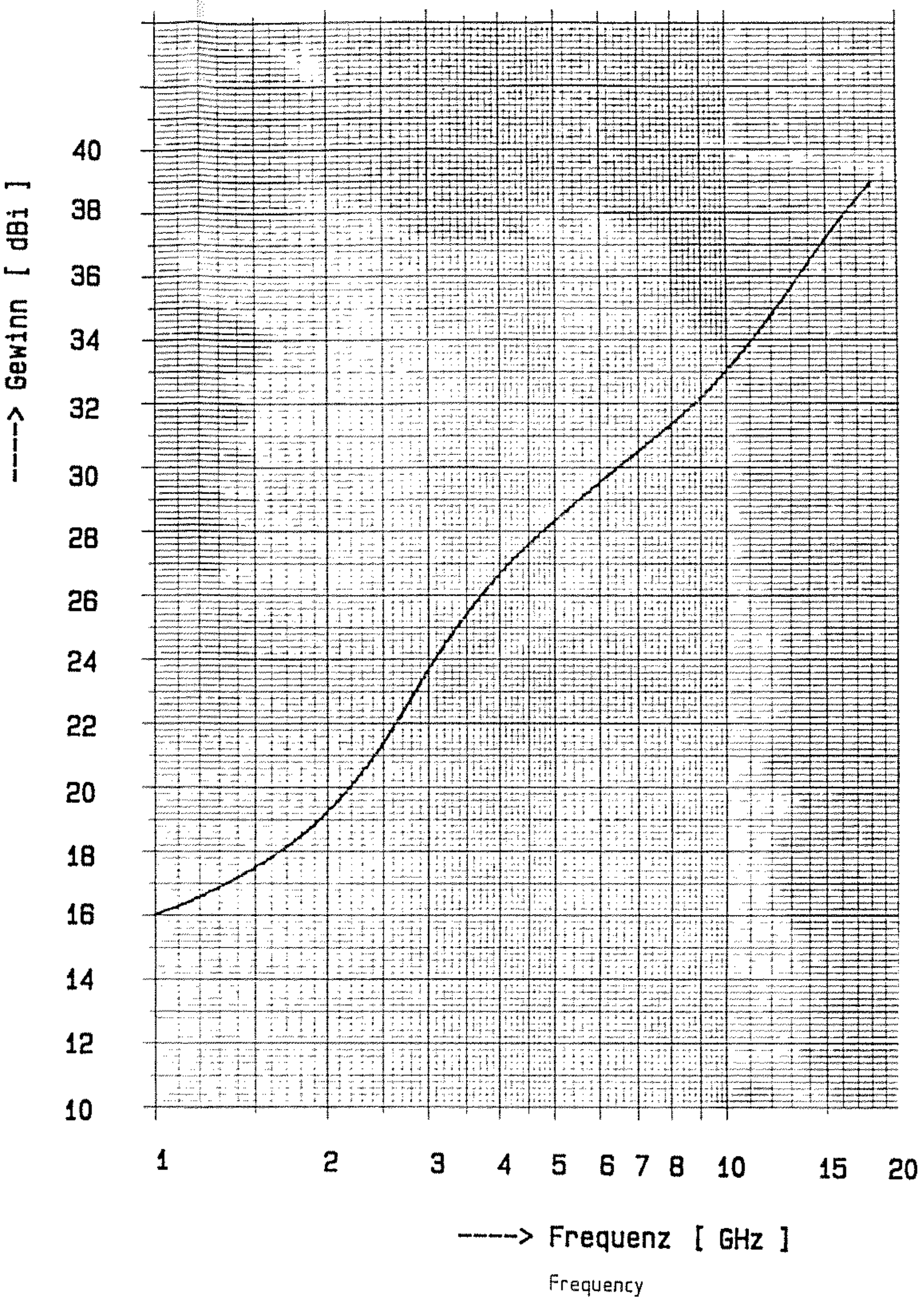


Bild 11 Gewinnverlauf der AC 008 mit Erreger HL 024 A1
Fig. 11 Gain curve of AC 008 with Feed HL 024 A1

C Feed control unit GB016S5

1 Characteristics

1.1 Uses und Designation

Control Unit GB 016 S5 is used for controlling the polarization network, amplifiers and bypass switchover of the Log-periodic Antenna HL 024 S5 using negative logic. Polarization, amplifier and bypass settings can be selected manually using seven keys.

Des. / Polariz.	HL 024 S5
Byp	S3
Amp.1	S4
Amp.2	S5
Amp.3	S6
Amp.4	S7
Test on	S2
Test off	S2
H	S1
V	S1
Logic	neg.

GB 016 S5 can be operated from an AC supply voltage between 85 V to 264 V. In the case of mobile use, GB 016 S5 can be powered with an external regulated DC voltage of +15 V ±5 %/< 3.5 A.

1.2 Technische Daten

Antenna control/power supply	
Antenna control X1	15-contact connector, female, DIN 41642
Power supply	
Voltage	85 VAC to 264 VAC, 50 Hz to 400 Hz (receptacle DIN 49457) or: 100 VDC to 375 VDC
Current	3 A_P (F1/F2: IEC127-T 3,15 H/250 V)
External DC supply at X3	
Voltage	+15 VDC ±5 % (stabilized)
Current	< 3.5 A
Dimensions (H x W x D)	approx. 0.12 m x 0.23 m x 0.3 m (½19": 2 E 1/2 T 250)
Weight	approx. 3.5 kg
Design and manufacture	meets ISO 9000, AQUAP 1, MIL-STD-454G
Operating temperature range	–10 °C to +55 °C to MIL-STD-810E Meth. 501.3 and 502.3
Storage temperature range	–40 °C to +85 °C to MIL-STD-810E Meth. 501.3 and 502.3
Humidity	+25/+55°C to DIN IEC 68-2-30
Vibration resistance	sinewave 5 to 55 Hz, 0.15 mm const. amplitude 55 to 150 Hz, 0.5 g const. to DIN IEC 68, section 2-6, MIL-T-28800D, class 5 random 10 to 300 Hz: 0.01 g^2/Hz 300 to 500 Hz: 0.003 g^2/Hz to DIN IEC 68-2-36
Shock resistance	max. 40 g, spectrum 45 Hz to 2000 Hz to MIL-STD-810D Method 516.3
Safety class	IP40 to DIN 40050
MTBF (SN29500 at T_U = 40°C, Gf[1])	> 300.000 h (100 % ED)

1.3 Equipment Supplied

Control Unit GB 016 S5	Order No. 4060.9500.02
Manual	Order No. 4060.9545.34

1.4 Recommended Extras

Control cable, 5 m	Order No. 4060.9951.02
Control cable, 10 m	Order No. 4060.9951.03

[1] Ground fixed

D N9344C spectrum analyzer specifications

Specifications

Specification			Supplemental information
Frequency			
Frequency range		1 MHz to 20 GHz (usable to 9 kHz)	AC coupled
Internal 10 MHz frequency reference accuracy			
Aging rate		± 1 ppm/year	
Temperature stability		± 1 ppm	Referenced to frequency reading at 25 °C. Temperature varied at max. of 2 °C per minute. Control voltage held at voltage control range midpoint
Frequency readout accuracy with marker (start, stop, center, marker)			
Marker resolution		(frequency span)/(sweep points - 1)	
Uncertainty		± (frequency indication × frequency reference uncertainty + 1% × span + 20% × resolution bandwidth + marker resolution + 1 Hz)	Frequency reference uncertainty = (aging rate × period of time since adjustment + temperature stability)
Marker frequency counter			
Resolution		1 Hz	
Accuracy		± (marker frequency × frequency reference uncertainty + counter resolution)	RBW/span ≥ 0.02; marker level to displayed noise level > 25 dB; frequency offset 0 Hz
Frequency span			
Range		0 Hz (zero span), 100 Hz to 20 GHz	
Resolution		1 Hz	
Accuracy		± (0.22% × span + span/(sweep points - 1))	Nominal
SSB phase noise			
Carrier offset	30 kHz	< –86 dBc/Hz, typical –89 dBc/Hz	20 to 30 °C
	100 kHz	< –97 dBc/Hz, typical –99 dBc/Hz	Center frequency 500 MHz
	1 MHz	< –115 dBc/Hz, typical –119 dBc/Hz	
Resolution bandwidth (RBW)			
–3 dB bandwidth		10 Hz to 3 MHz	1-3-10 sequence
Accuracy		± 5%, RBW = 10 Hz to 1 MHz	Nominal
		± 10%, RBW = 3 MHz	
Resolution filter shape factor		< 5:1	Nominal; 60 dB/3 dB bandwidth ratio; digital, Gaussian-like
EMI bandwidth (CISPR compliant)		200 Hz, 9 kHz, 120 kHz, 1 MHz	Option EMC required
Accuracy		± 10% nominal	
Resolution filter shape factor		< 5:1 nominal	–60 dB/–6 dB bandwidth ratio
Video bandwidth (VBW)			
–3 dB bandwidth		1 Hz to 3 MHz	1-3-10 sequence
Accuracy		± 10%, VBW = 1 Hz to 1 MHz	Nominal

Specifications (continued)

Amplitude specifications				Supplemental information
Measurement range				
1 to 500 MHz		Displayed average noise level (DANL) to +10 dBm		Preamp off
500 MHz to 20 GHz		Displayed average noise level (DANL) to +20 dBm		
Input attenuator range		0 to 50 dB, in 5 dB steps		
Maximum safe input level				
Average continuous power		+30 dBm, 3 minutes maximum		Input attenuator setting ≥ 20 dB, 1 MHz to 20 GHz
DC voltage		± 50 VDC maximum		
Displayed average noise level [1]				
Preamp off		**Normalized to 1 Hz**	**Minimum RBW**	
1 to 10 MHz		–125 dBm, typical –140 dBm	–115 dBm, typical –130 dBm	Reference level ≤ –50 dBm
10 MHz to 3 GHz		–137 dBm, typical –142 dBm	–127 dBm, typical –132 dBm	
3 to 7 GHz		–135 dBm, typical –140 dBm	–125 dBm, typical –130 dBm	
7 to 10 GHz		–139 dBm, typical –142 dBm	–129 dBm, typical –132 dBm	
10 to 13 GHz		–137 dBm, typical –140 dBm	–127 dBm, typical –130 dBm	
13 to 16 GHz		–136 dBm, typical –139 dBm	–126 dBm, typical –129 dBm	
16 to 18 GHz		–134 dBm, typical –139 dBm	–124 dBm, typical –129 dBm	
18 to 20 GHz		–126 dBm, typical –131 dBm	–116 dBm, typical –121 dBm	
Preamp on				
1 to 10 MHz		–140 dBm, typical –156 dBm	–130 dBm, typical –146 dBm	Reference level ≤ –70 dBm
10 MHz to 3 GHz		–150 dBm, typical –154 dBm	–140 dBm, typical –144 dBm	
3 to 6 GHz		–145 dBm, typical –150 dBm	–135 dBm, typical –140 dBm	
6 to 13 GHz		–151 dBm, typical –155 dBm	–141 dBm, typical –145 dBm	
13 to 16 GHz		–149 dBm, typical –153 dBm	–139 dBm, typical –143 dBm	
16 to 18 GHz		–147 dBm, typical –151 dBm	–137 dBm, typical –141 dBm	
18 to 20 GHz		–137 dBm, typical –142 dBm	–127 dBm, typical –132 dBm	
Level display range				
Log scale		10 to 100 dB, 10 divisions displayed, 1, 2, 5, 10 dB/division		
Linear scale		0 to 100%, 10 divisions displayed		
Scale units		dBm, dBmV, dBµV, W, V, dBmV EMF, dBµV EMF, V EMF		
Sweep (trace) points		461		
Number of markers		6		
Marker functions		Normal, frequency counter, noise marker, band power and AM/FM demod (tune and listen)		
Marker level readout resolution	Log scale	0.01 dB		
	Linear scale	≤ 1% of signal level		Nominal
Detectors		Normal, positive peak, sample, negative peak, average (video, RMS, voltage), quasi-peak (option EMC required)		
Number of traces		4		
Trace functions		Clear/write, maximum hold, minimum hold, average		

1. RMS detector, trace averaging > 40, 0 dB input attenuation, input terminated 50 Ω, 1 kHz resolution bandwidth, 20 to 30 °C.

Specifications (continued)

Amplitude specifications (continued)				Supplemental information
Level display range (continued)				
Level measurement error	1 MHz to 7 GHz	Excluding input VSWR mismatch ± 1.3 dB		– 20 to 30 °C, 30 to 70% RH, peak detector, preamp off, input signal –50 to 0 dBm, 95% percentile – Swp Time Rule is set to Accuracy – Adds ± 0.3 dB when Swp Time Rule is set to Speed – Adds ±0.3 dB with 5-minute warm-up
	7 to 18 GHz	± 1.6 dB		
	18 to 20 GHz	± 1.8 dB		
Reference level [2]				
Setting range		–100 to +30 dBm		Steps of 1 dB
Setting resolution	Log scale	0.01 dB		
	Linear scale	Same as log (2.236 µV to 7.07 V)		
Accuracy		0		
RF input VSWR (at tuned frequency)				
1 MHz to 7 GHz		< 1.5:1		Nominal, ≥ 10 dB attenuation
7 to 18 GHz		< 2:1		
18 to 20 GHz		< 2.5:1		
Spurious response				
Second harmonic distortion		< –65 dBc, typical < –70 dBc, 50 MHz to 7 GHz		Mixer signal level at –30 dBm, input attenuation 0 dB, preamp off, 20 to 30 °C
		< –80 dBc, typical < –90 dBc, 7 to 20 GHz		
Third order intermodulation distortion (third order intercept)		5-min warm-up	30-min warm-up	Two –20 dBm tones at input mixer, spaced by 100 kHz, input attenuation 0 dB, preamp off, reference level ≥ –30 dBm, 20 to 30 °C
	50 to 300 MHz	+6.5 dBm, typical +7.5 dBm	+8 dBm, typical +9 dBm	
	300 MHz to 8 GHz	+7.5 dBm, typical +9.5 dBm	+9 dBm, typical +11 dBm	
	8 to 13 GHz	+8.5 dBm, typical +10.5 dBm	+10 dBm, typical +12 dBm	
	13 to 20 GHz	+11.5 dBm, typical +13.5 dBm	+13 dBm, typical +15 dBm	
Input related spurious		< –59 dBc, typical < –69 dBc	< –60 dBc, typical < –70 dBc	– –30 dBm signal at input mixer, span < 2.9 GHz – Exception: –55 dBc (2 × F1 = center frequency –5,890 MHz, 7 GHz < center frequency < 10 GHz, with F1 input frequency)
Inherent residual response	1 MHz to 7 GHz	< –93.5 dBm, typical –108.5 dBm	< –95 dBm, typical –110 dBm	Input terminated and 0 dB RF attenuation, preamplifier off
	7 GHz to 20 GHz	< –83.5 dBm, typical –91.5 dBm	< –85 dBm, typical –93 dBm	

2. Reference level only affects the display not the measurement, so trace data markers do not cause additional errors in measurement results.

Specifications (continued)

Sweep specifications		Supplemental information
Sweep time		
Range	2 ms to 1000 s	Span ≥ 100 Hz
	600 ns to 200 s	Span = 0 Hz (zero span)
Sweep mode	Continuous, single	
Sweep time rule	Accuracy, speed	
Trigger source	Free run, video, external, RF burst	
Trigger slope	Selectable positive or negative edge	
Trigger delay	± 12 ms to ± 12 s	Nominal, span = 0 Hz (zero span)

Front panel input/output		Supplemental information
RF input		
Connector and impedance	Type-N female, 50 Ω	Nominal
10 MHz reference/external trigger input		
Reference input frequency	10 MHz	
Reference input amplitude	0 to +10 dBm	
Trigger voltage	5 V TTL level	Nominal
Connector	BNC female, 50 Ω	Nominal
Probe power		
Voltage/current		+15 Vdc, ± 7% at 0 to 150 mA (nominal)
		–12.6 Vdc, ± 10% at 0 to 150 mA (nominal)
		GND
Connectivity		
USB host	USB Type-A female, compatible with USB 2.0 full speed	
USB device	USB Type-mini AB female, compatible with USB 2.0 full speed	
LAN	RJ-45, 10 Base-T	

General specifications		Supplemental information
Display		
Resolution	640 pixels x 480 pixels	
Size and type	170 mm (6.5 in) TFT color display	
Internal memory		
System memory	64 MB	For system use. Not user accessible
User memory	64 MB	User accessible. Able to store about 14,000 traces
Languages		
On-screen GUI	English, Simplified Chinese, Traditional Chinese, French, German, Italian, Japanese, Korean, Russian, Spanish, Portuguese	

Specifications (continued)

General specifications (continued)		Supplemental information
Power requirements and calibration		
Adaptor voltage	100 to 240 V AC, 50 to 60 Hz	Auto-ranging
	15 V DC, 5.3 A, 80 W max	
Power consumption	16 W	Typical
Battery operating time (fully charged battery)	3.5 hours	Tracking generator off, preamplifier on
	3 hours	Tracking generator on, preamplifier on
Charging time	3 hours	
Life time	300 to 500 charge cycles	
Warm-up time	5 minutes	
Calibration cycle	One year	
Environmental and size		
Temperature range	–10 to +50 °C	Operating (battery: 0 to 50 °C)
	–40 to +70 °C	Storage (battery: –20 to 50 °C)
Altitude	9,144 meters (30,000 feet)	Operating with battery
	3,000 meters (9,840 feet)	Operating with AC to DC adapter
	15,240 meters (50,000 feet)	Non-operating
Relative humidity	< 95%	
Weight	3.2 kg (7 lbs)	Net (shipping) approximately, 3.6 kg (7.9 lbs) with battery
Dimensions	318 mm × 207 mm × 69 mm (12.5 in × 8.15 in × 2.7 in)	Approximately (W × H × D)

Option specifications		Supplemental information
Channel scanner (Option SCN)		
Scan modes	Top N, bottom N, and list	
Channels displayed	1 to 20	
Display orientation	Vertical	Number of channels ≤ 5
	Horizontal	Number of channels > 5
Chart	Bar chart, and time chart	
Log file	.CSV and .KML	
Radio standards	Pre-defined and user-defined. Pre-defined standards include the major wireless communication standards such as GSM, CDMA, W-CDMA, LTE, WiMAX, etc.	
Spectrum monitor (Option SIM)		
Display modes	Spectrogram	
	Spectrum trace	
	Combination of spectrogram and spectrum trace in one screen	
RF preamplifier (Option P20)		
Frequency range	1 MHz to 20 GHz	
Gain	15 dB	Nominal
Tracking generator (Option TG7)		
Frequency range	5 MHz to 7 GHz	
Output level	0 to –20 dBm	1 dB steps
VSWR	< 2.0:1	Nominal
Connector and impedance	Type-N female, 50 Ω	

Specifications (continued)

Option specifications (continued)		Supplemental information
AM/FM modulation analysis (Option AMA)		
Frequency range	10 MHz to 20 GHz	
Carrier power accuracy	< 7 GHz, ± 1.5 dB	Nominal
	7 to 18 GHz, ± 1.8 dB	Nominal
	18 to 20 GHz, ± 2.0 dB	Nominal
Carrier power range	–30 to +10 dBm	1 to 500 MHz
	–30 to +20 dBm	500 MHz to 20 GHz
Carrier power displayed resolution	0.01 dBm	
AM measurement		
Modulation rate	20 Hz to 100 kHz	
Accuracy	1 Hz	Nominal (modulation rate < 1 kHz)
	< 0.1% modulation rate	Nominal (modulation rate > 1 kHz)
Depth	5 to 95%	
Accuracy	± 4%	Nominal
FM measurement		
Modulation rate	20 Hz to 200 kHz	
Accuracy	1 Hz	Nominal (modulation rate < 1 kHz)
	< 0.1% modulation rate	Nominal (modulation rate > 1 kHz)
Depth	20 Hz to 400 kHz	
Accuracy	± 4%	Nominal
ASK/FSK modulation analysis (Option DMA)		
Frequency range	2.5 MHz to 6 GHz	
Carrier power accuracy	± 2 dB	Nominal
Carrier power range	–30 to +20 dBm	Nominal
Carrier power displayed resolution	0.01 dBm	
ASK measurement		
Symbol rate range	100 Hz to 100 kHz	
Modulation depth/index	5 to 95%	
Accuracy	± 4%	Nominal
Displayed resolution	0.1%	
FSK measurement		
FSK deviation	100 Hz to 400 kHz	
Symbol rate range	100 Hz to 20 kHz	$1 \leq \beta^* \leq 20$
	20 to 50 kHz	$1 \leq \beta \leq 8$
	50 to 100 kHz	$1 \leq \beta \leq 4$
Accuracy	± 4%	Nominal
Displayed resolution	0.01 Hz	
Time-gated spectrum analysis (Option TMG)		
Gated sweep		
Span range	Any span	
RBW range	> = 1 kHz	VBW is fixed and equal to RBW [3]
Gate delay range	12 µs to 10 s	200 ns resolution
Gate length range	84 µs to 10 s	200 ns resolution

* β is the ratio of frequency deviation to symbol rate (deviation/rate).

Specifications (continued)

Option specifications (continued)		Supplemental information
Time-gated spectrum analysis (Option TMG)		
Gated sweep (continued)		
Gate sources	External	
	RF burst	
	Periodic timer	– Sync sources include free, external, and RF burst – Period: 0 to 20.0 s (It should be greater than gate delay plus gate length) – Offset: –5 to +5 s
RF burst		
Level range		–60 to –20 dBm plus attenuation (nominal)
Bandwidth (–10 dB)		8 MHz (nominal)
Frequency limitations		If the start or center frequency is too close to zero, LO feedthrough can degrade or prevent triggering. How close is too close depends on the bandwidth.
Built-in GPS receiver and GPS antenna (Option GPS)		
GPS information tagging	Longitude, latitude, and altitude	
GPS antenna	Built-in	
Frequency accuracy with GPS on	± 50 ppb	
External GPS antenna connector	SMA-F	External GPS antenna, N934xC-GPA, is offered as an optional accessory
USB peak and average power sensor support (Option PWP)		
Power sensor supported	Keysight U2020 X-series USB peak and average power sensor	
Frequency range	50 MHz to 40 GHz	Sensor dependent
Peak power dynamic range	–30 to +20 dBm	
USB average power sensor support (Option PWM)		
Power sensor supported	Keysight U2000 Series USB power sensor	
Frequency range	9 kHz to 24 GHz	Sensor dependent
Dynamic range	–60 to +44 dBm	Sensor dependent
Security features (Option SEC)		
Security erase	Erase the entire user flash memory by writing single character "1" over all memory locations	Non-recoverable
Port control	Disable/enable LAN port or USB port	
Task planner for test automation (Option TPN)		
Task plan execution mode	Auto, manual, and manual if fail	
Task plan file	.TPN	Complementary task plan editor is available with HSA PC software
Number of tasks	Maximum 20 in a single .TPN file	
Measurements supported	Regular spectrum analysis and power suite (channel power, ACPR, and OBW)	

Visit **www.keysight.com/find/taskplanner** for more information.

3. For efficiency and convenience, RBW is restricted to be equal to or greater than 1 kHz and VBW is restricted to be equal to RBW.