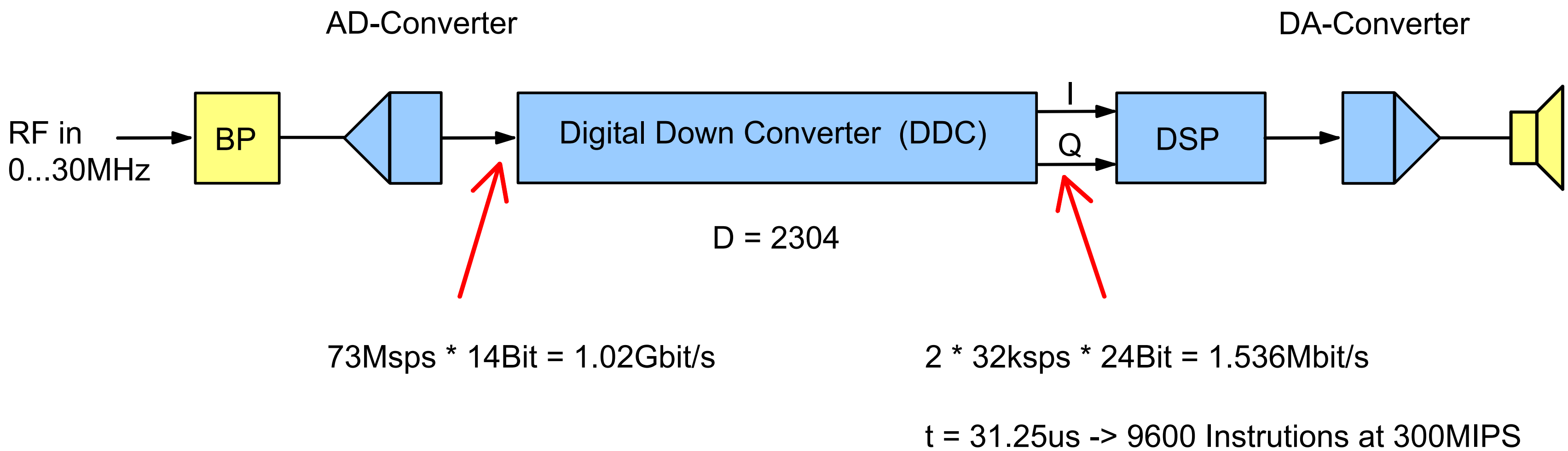
The Digital Transceiver ADT-200A

- The Principle of a Digital Receiver
  - AD Converter
  - The Problem with IP3
  - The Direct Conversion Rx
- The Functional Units of ADT-200A
  - DSP Module
  - PA Module
  - Preselector Module
- The Operating Concept of ADT-200A
- Where do we go from here?

Signal Flow in a fully digital Receiver



Tasks of the DDC:

- Quadrature Mixer with an IF ≈ 0Hz (Homodyne Receiver), NOT a Sampler
- Sample Rate Reduction by Decimation
- Improvement of S/N by Integration

The Dynamic Range of an AD-Converter

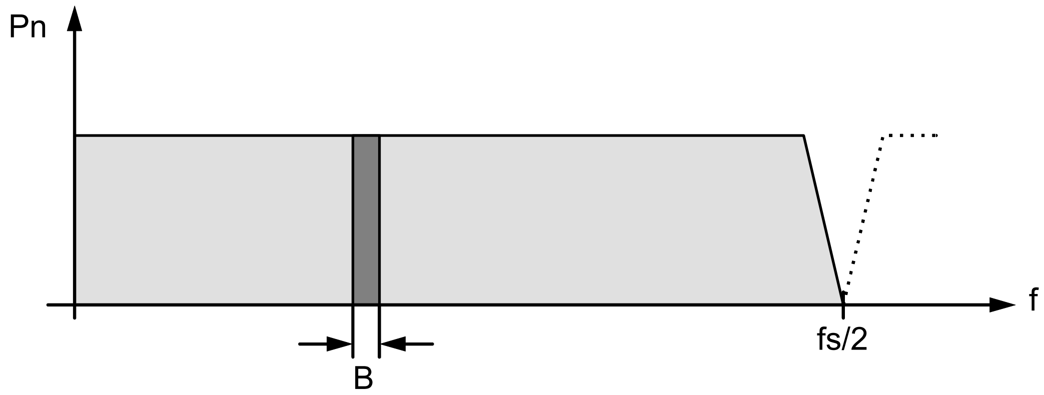
Example: 14Bit AD-Converter AD6645 from Analog Devices:

Dynamic Range (ideal) = 86dB (= SNR af fullscale input signal)
Dynamic Range (real) = 75dB → 12 effective Bits (ENOB)

Max. Input Power = $(0.78\text{Vrms})^2$ / 1000Ω = -2.2dBm
Noise Floor = -2.2dBm – 75dB = -77.2dBm

Minimum Input Voltage at 50Ω = 30.8µV

The Dynamic Range of an AD-Converter



Process Gain:

$$Gp = 10 \cdot LOG_{10}\left(\frac{fs}{2 * B}\right)$$

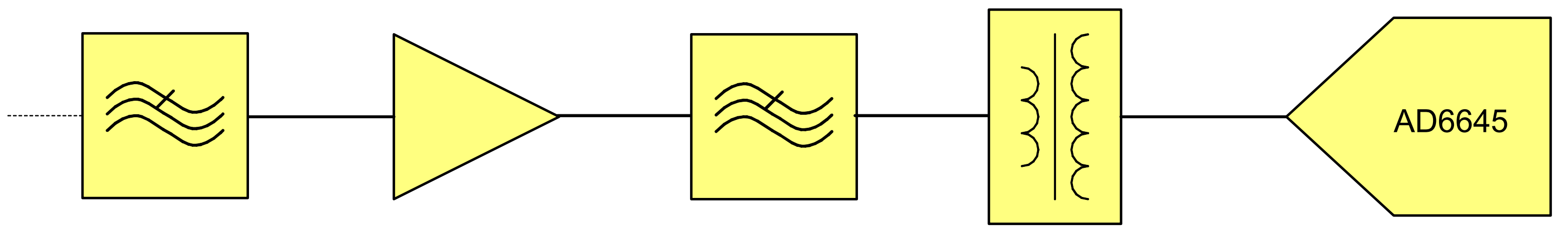
For B = 2.4kHz and fs = 73Msps :
Gp = 44.8dB → SNR = 119.8dB

Noise Floor in 50Ω = 0.22μV

The Principle of a Digital Receiver

The Calculation of Receiver Performance

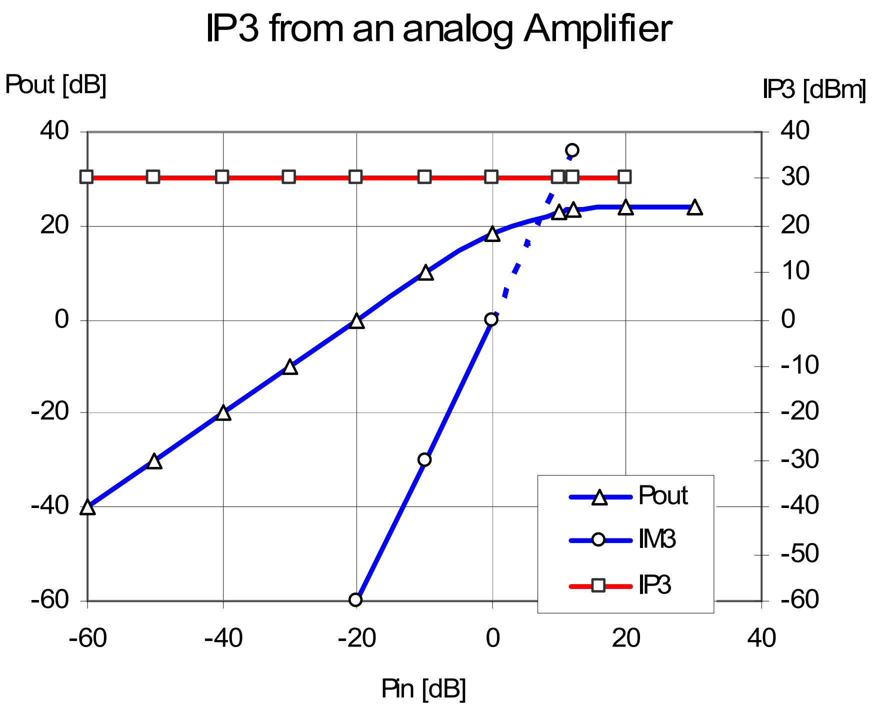
Preselector | Preamplifier | Antialiasing-Filter | Transformer 1:4 | AD-Converter



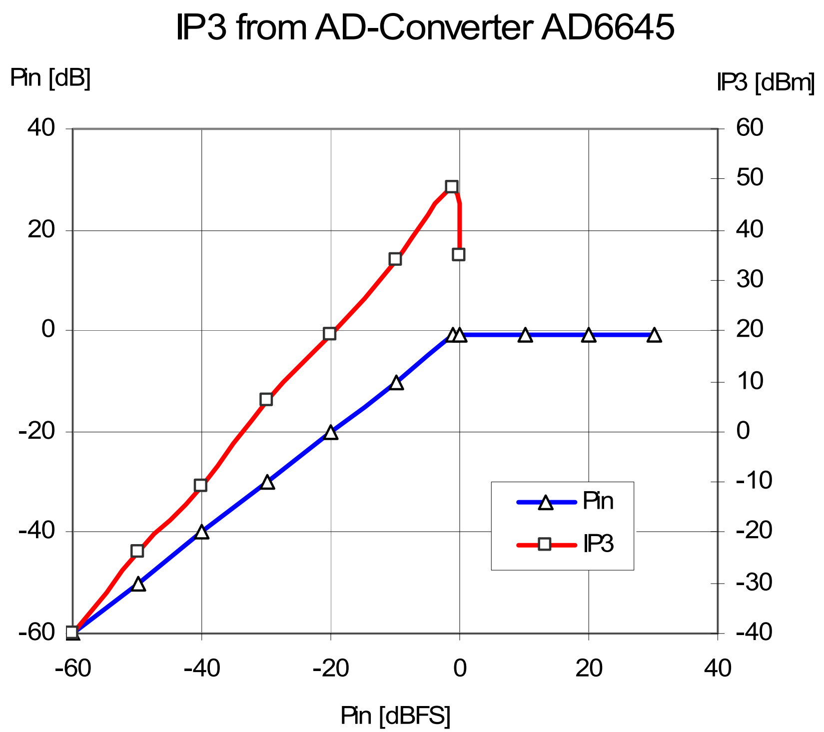
Preselector	Preamplifier	Antialiasing-Filter	Transformer 1:4	AD-Converter
Gain = -2dB	Gain = 14dB F = 3dB $IP3_{out}$ = 39dB	Gain = -1dB fg = 32MHz	Zin/Zout = 1:16 Gain = -0.5dB	Uin_{max} = 2.2Vpp Zin = 800Ohm F = 20.8dB

Noise Figure	Fges	= 11.4dB
Sensitivity	MDS	= -129dBm @ B=2.4kHz (0.08uV)
Dynamic Range	DR	= 117dB
IM3 free Dynamic Range	DR3	= 101dB
Max. Input Power	Pmax	= -11.4dBm

The Problem with Intercept Point (IP3) Measurement

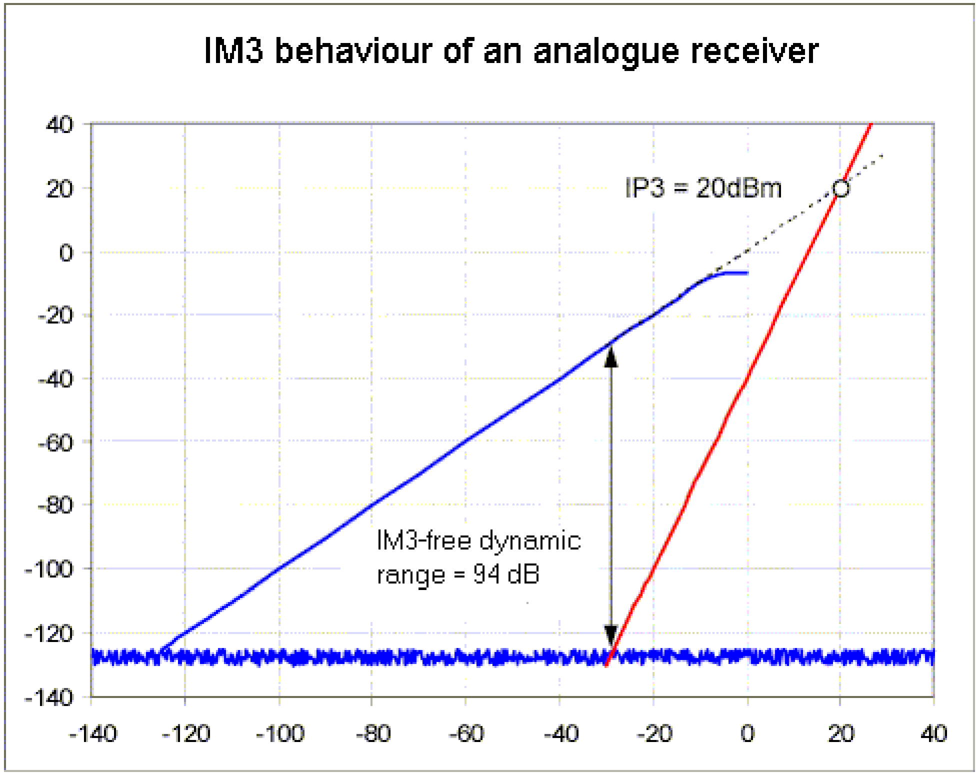


IM3 product increases 3dB per 1dB of signal

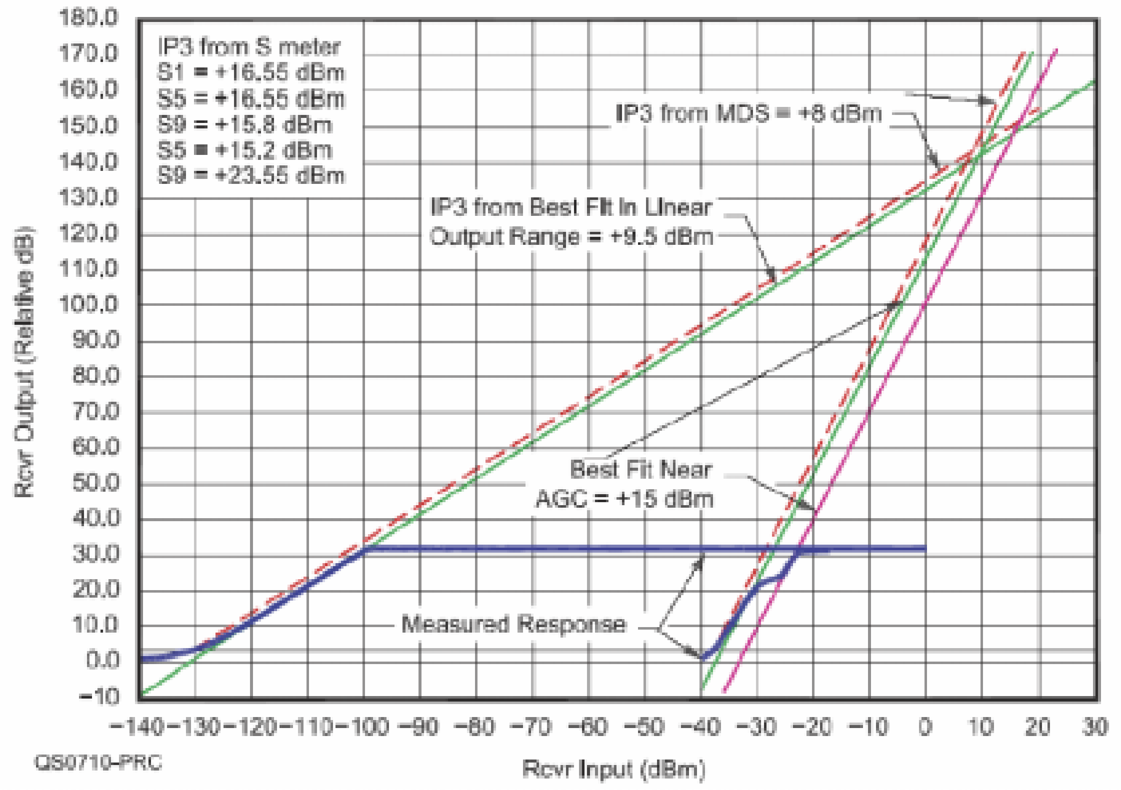


IM3 product is nearly independent of signal

The Problem with Intercept Point (IP3) Measurement

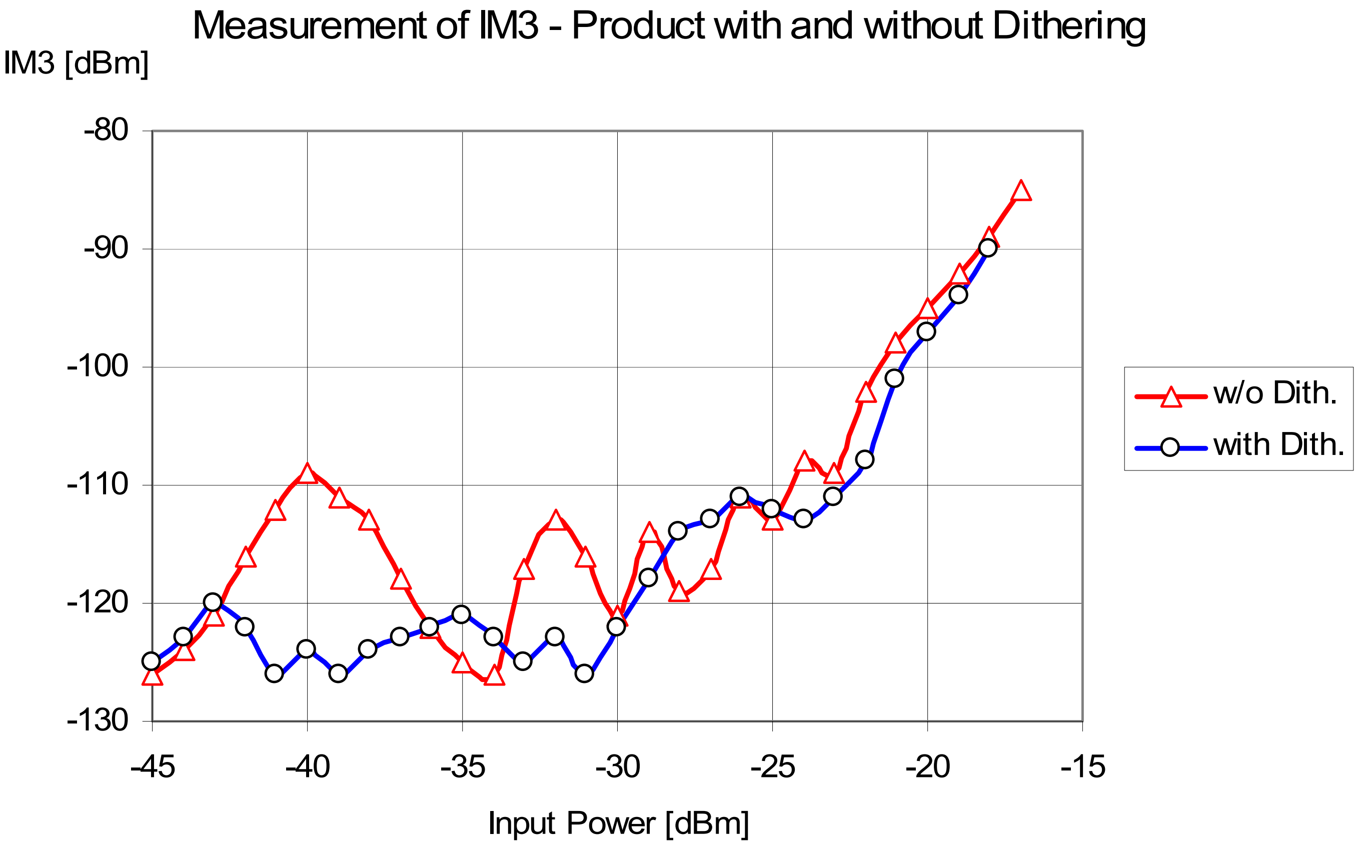


The Problem with Intercept Point (IP3) Measurement

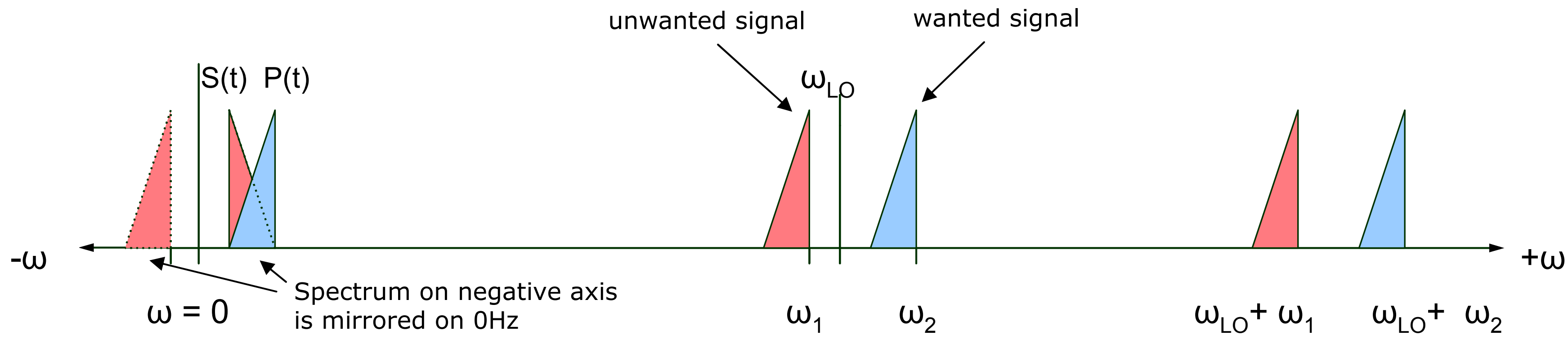


Excerpt from ARRL Lab Test Report

The Problem with Intercept Point (IP3) Measurement



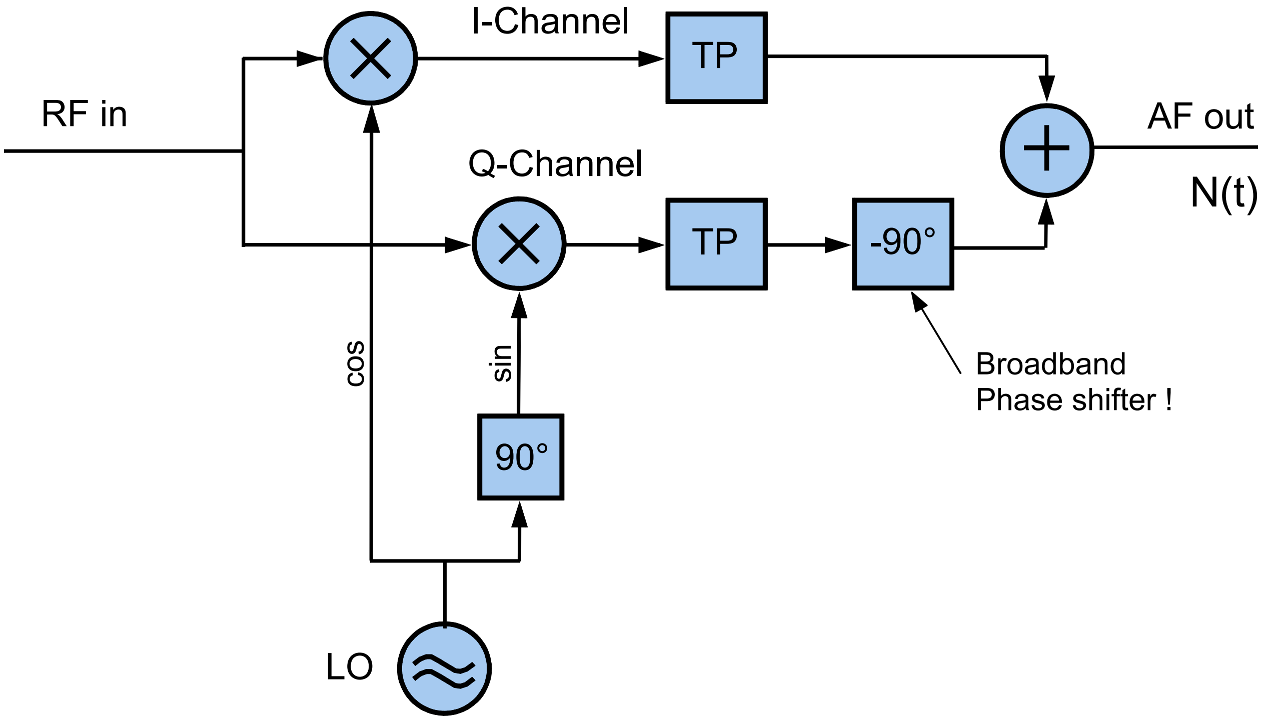
Principle of Direct Conversion Receiver



I-Channel Q-Channel

$$S(t) = A(t) \cdot e^{j \cdot \omega t} = A(t) \cdot [\cos(\omega t) + j \cdot \sin(\omega t)]$$

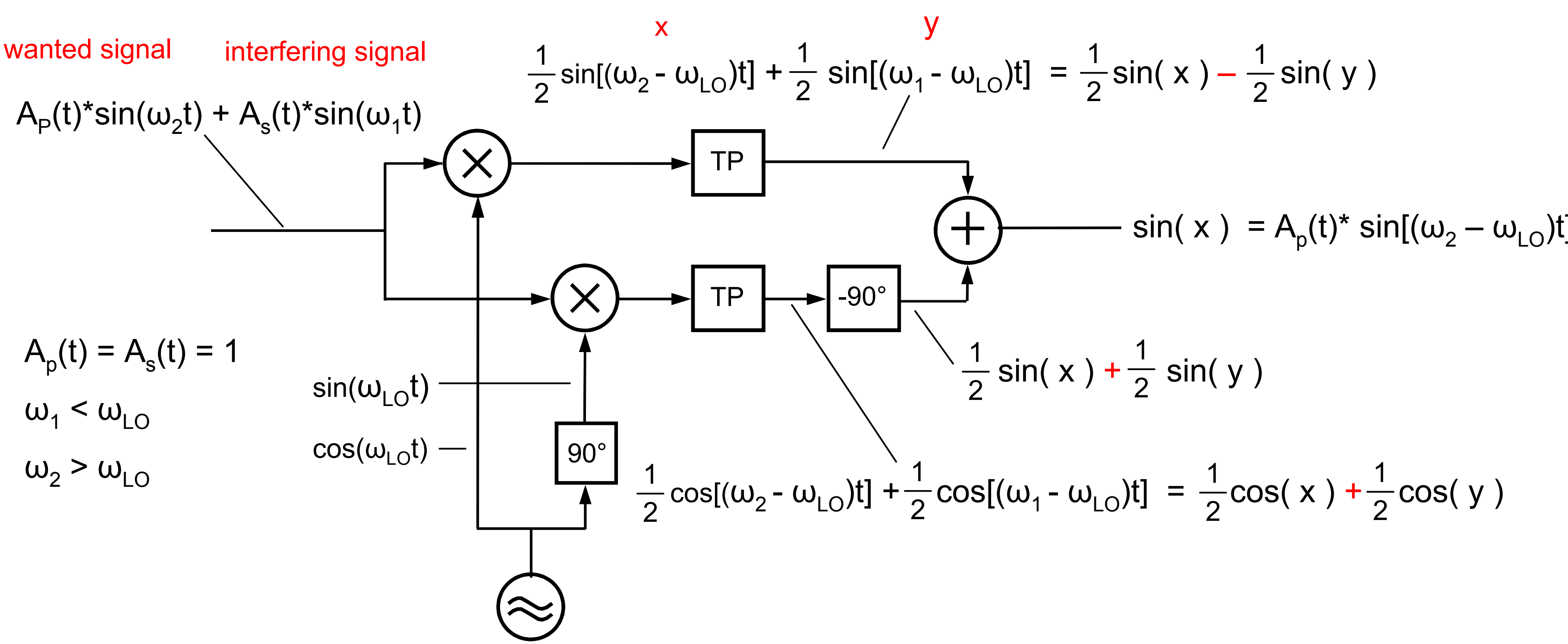
The Direct Conversion (Quadrature) Receiver



TP = Low-Pass Filter

The Principle of a Digital Receiver

Mathematical Background of a Direct Conversion Receiver

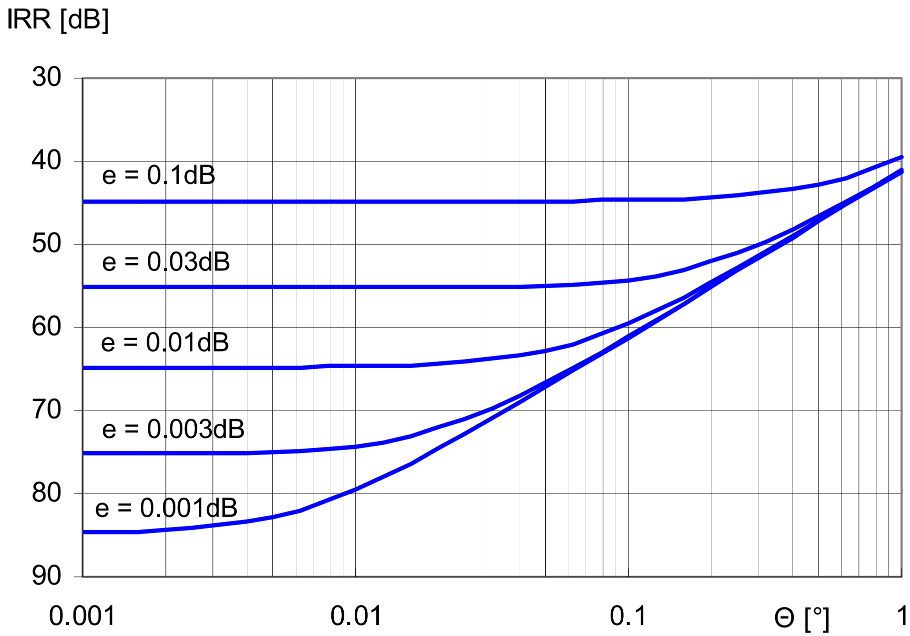


TP = Low-Pass Filter

Principle of the Direct-Conversion Receiver

The Image Rejection Ratio IRR

$$\mathrm{IRR} = \frac{1 - 2(1+\epsilon)\cos\theta + (1+\epsilon)^2}{1 + 2(1+\epsilon)\cos\theta + (1+\epsilon)^2}$$



ε : Gain Error [-]

Θ : Phase Error [°]

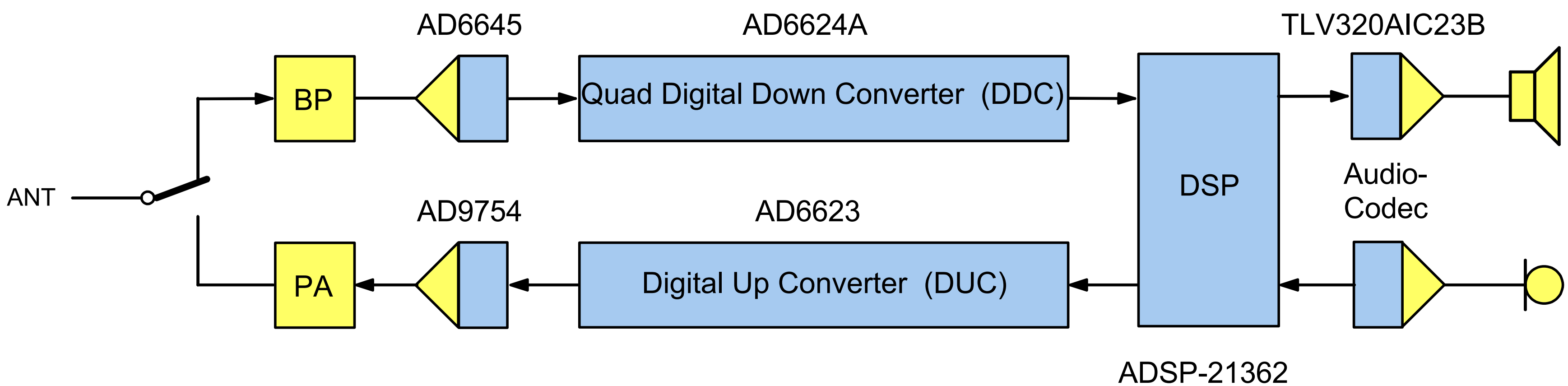
e = 20 * log(ε)

Principle of the Digital Receiver

How does SDR technology benefit the radio amateur?

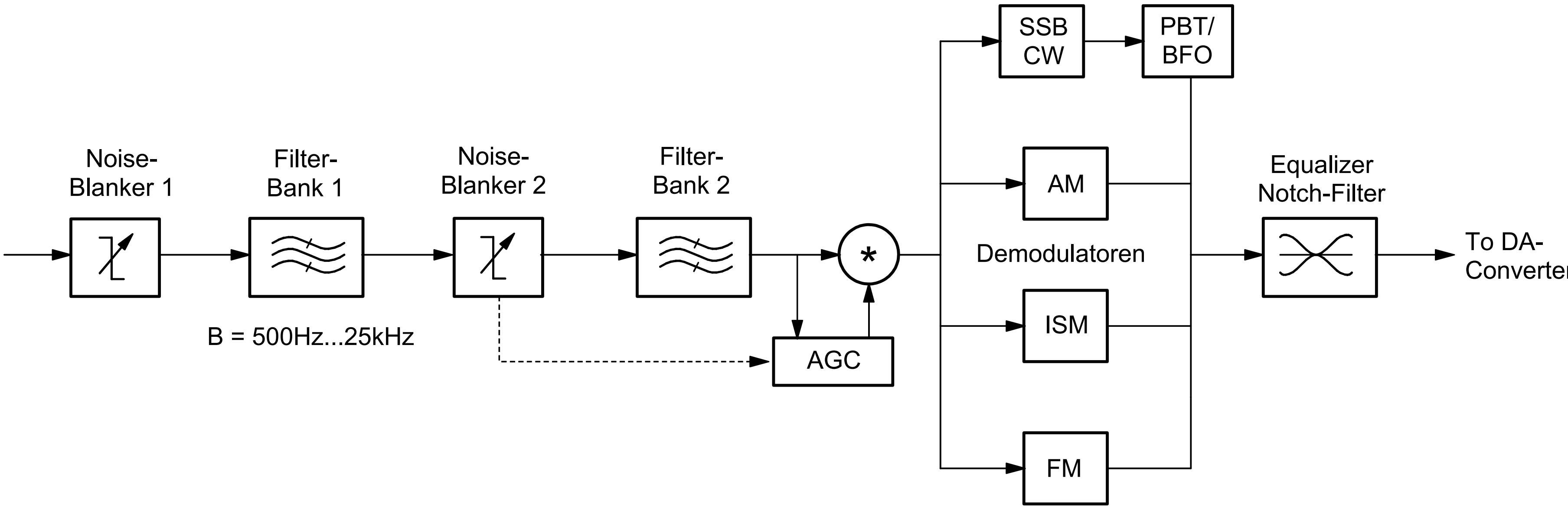
- a radio which can be retrofitted with new features at any time
- Characteristics which are largely independent of tolerances and ageing
- accuracy approaching that of measuring instruments
- Special features such as Antennascope, Audio Recorder, Remote Operation etc.
- A future-oriented technology, which is implemented with a fraction of the components utilized in current radio equipment
- This technology lends itself to automated manufacturing, with a corresponding cost savings

Functional Blocks of ADT-200A



Chipset of DSP Module

Functional Blocks of ADT-200A



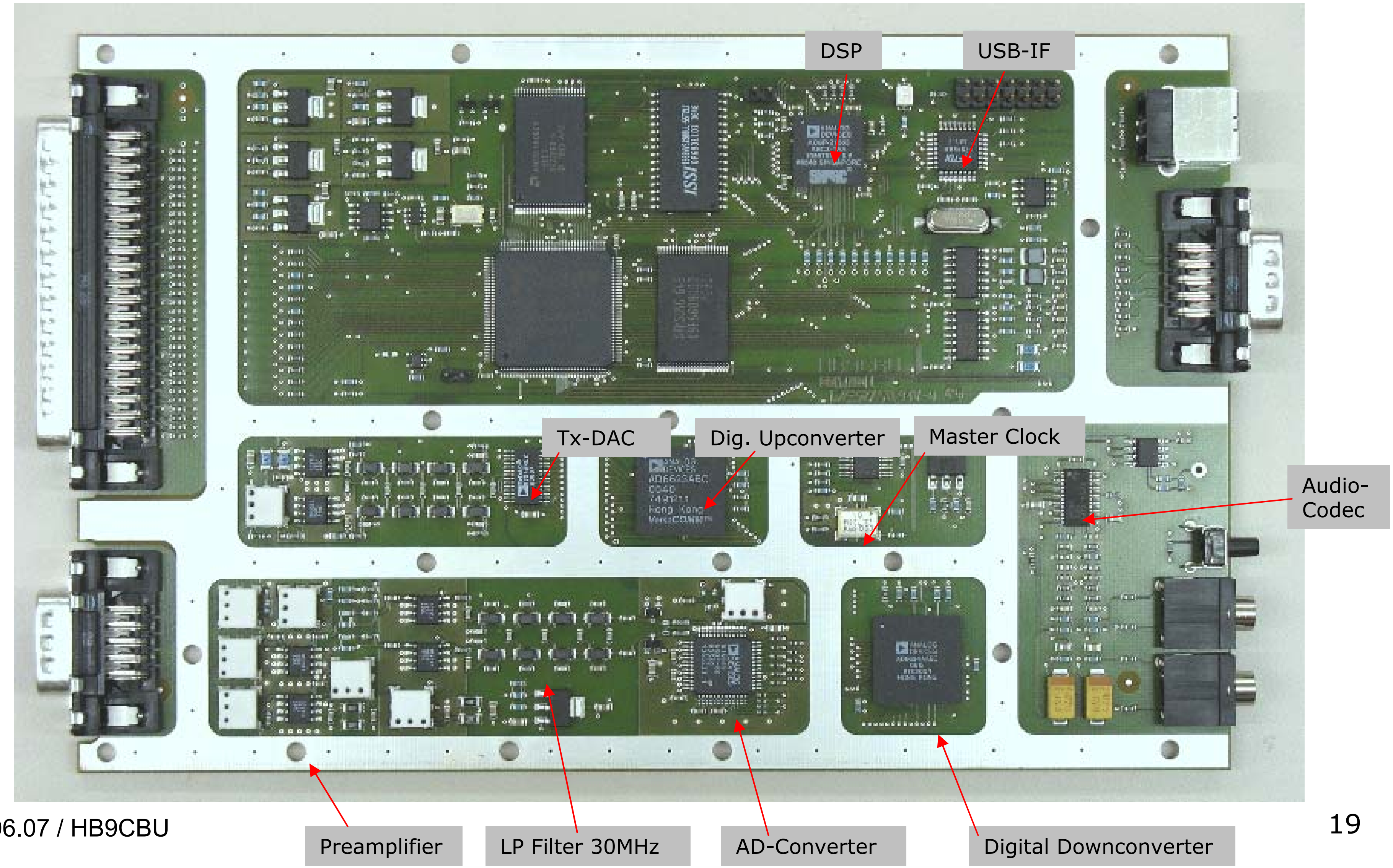
Signal Processing on DSP (per Channel)

Signal Processing Example

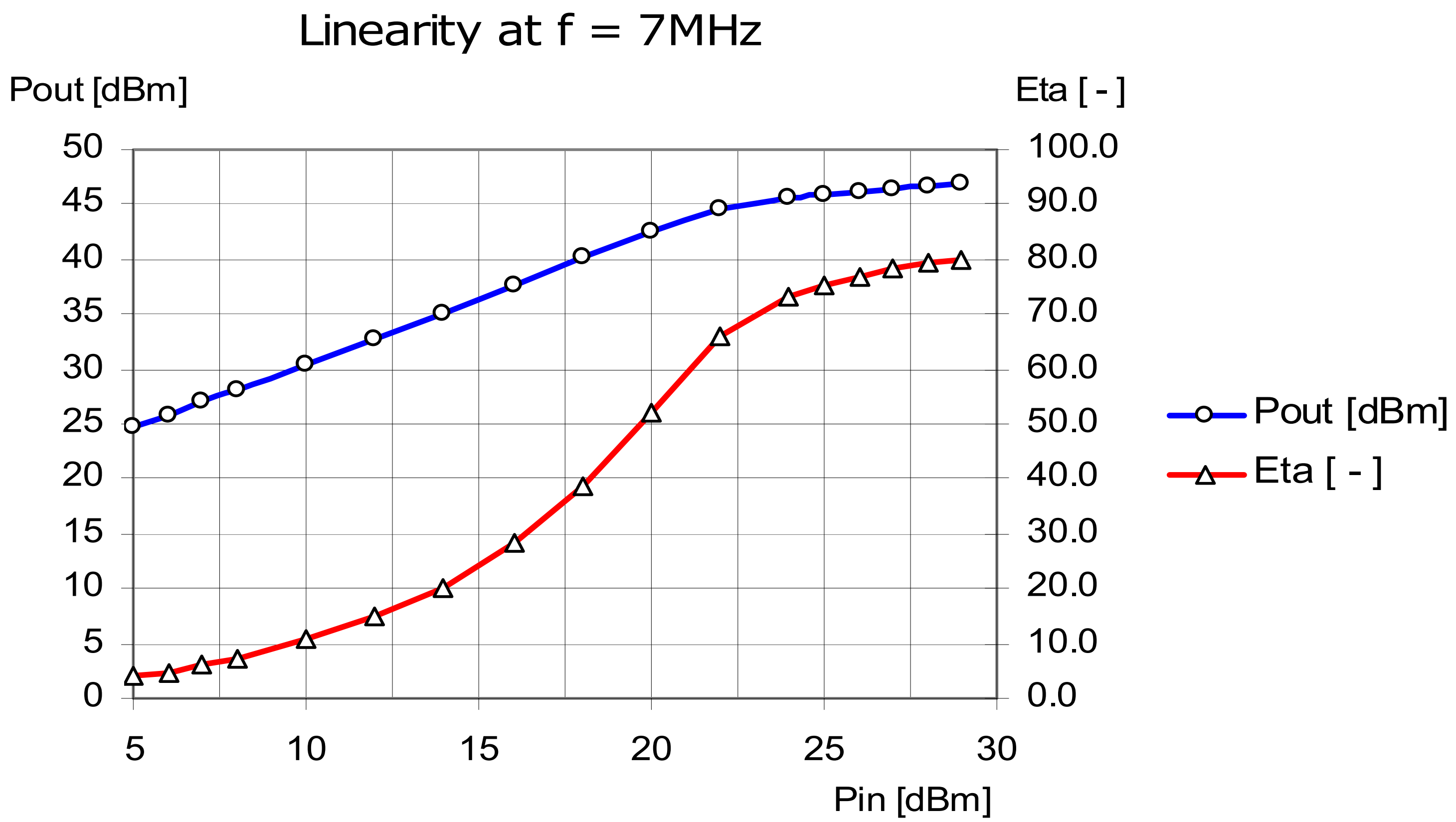
```
/****************************************************************************
**  FM_Demodulator
****************************************************************************/

FM_Demodulator:

/*  first, we calculate the squared absolut carrier value */

     F3 = F1 * F1;             /* F1  -> I channel input  */
     F4 = F2 * F2;             /* F2  -> Q channel input  */
     F12 = F3 + F4;            /* F12 -> I^2 + Q^2 */
     F13 = RSQRTS F12;         /* F13 -> 1/SQR(I^2 + Q^2) */
     F1 = F1 * F13;            /* normalize F1 */
     F2 = F2 * F13;            /* normalize F2 */

/*  then, we get the phase info by delay modulation */

     F5 = DM(last_I);
     F5 = F1 - F5;             /* build d/dt -> I'    */
     F5 = F5 * F2;             /* product    -> I'* Q */

     F6 = DM(last_Q);
     F6 = F2 - F6;             /* build d/dt -> Q'    */
     F6 = F6 * F1;             /* product    -> Q'* I */

     DM(last_I) = F1;          /* save normalized last_I */
     DM(last_Q) = F2;          /* save normalized last_Q */

     F1 = F5 - F6;             /* I'*Q - Q'*I */
     CALL ARCSIN;
     DM(FM_out) = F3;
```

Functional Blocks of ADT-200A

The TRX3C DSP Module



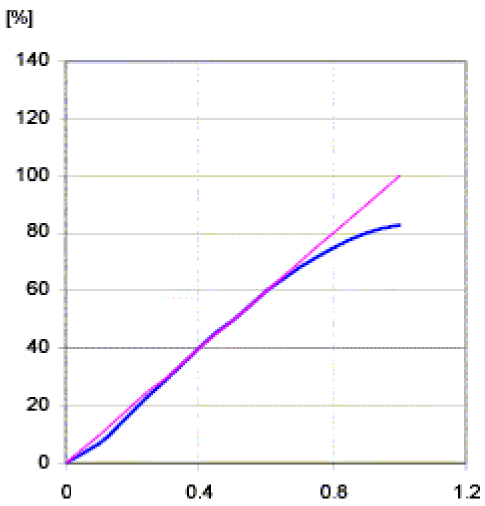
The Power Amplifier



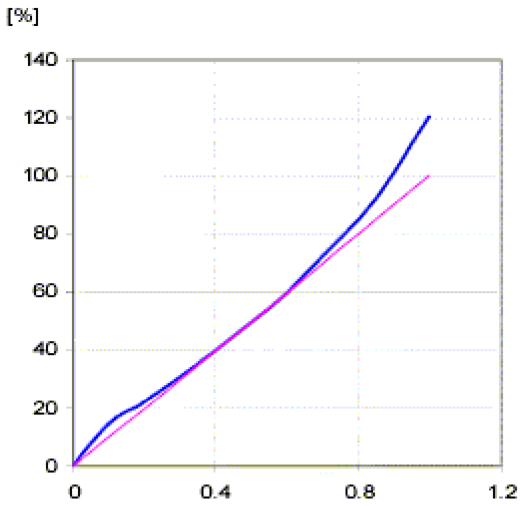
Functional Blocks of the ADT-200A

The Transmitter Power Amplifier

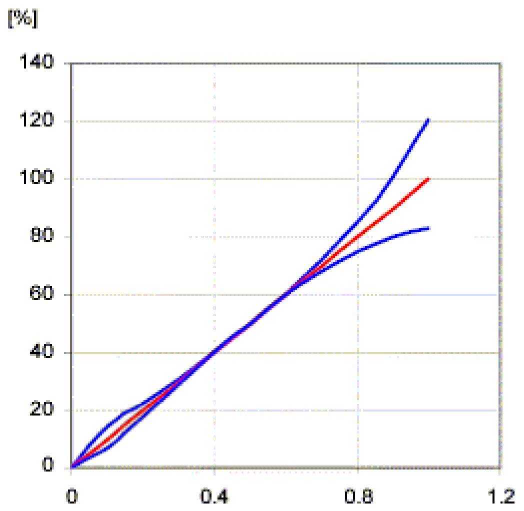
Principle of Adaptive Predistortion



PA Transfer Characteristic



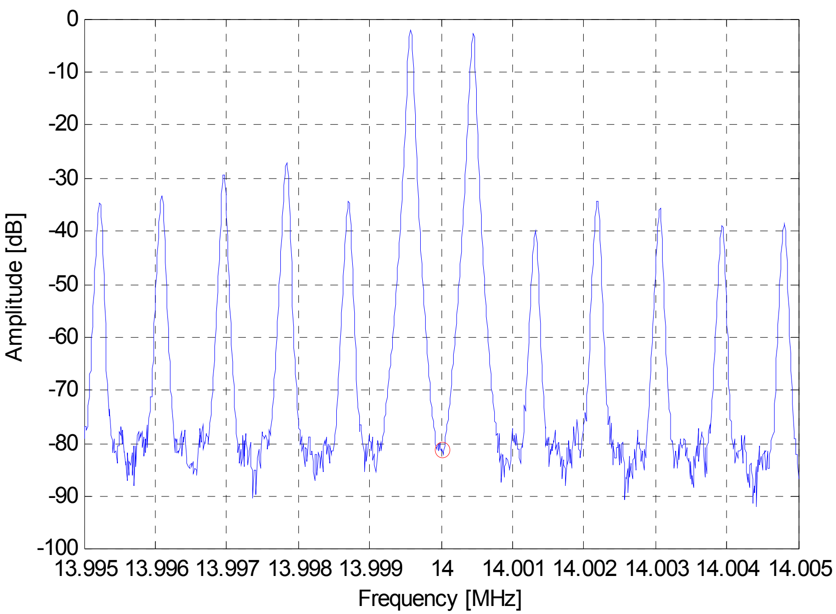
Deviation from Linearity



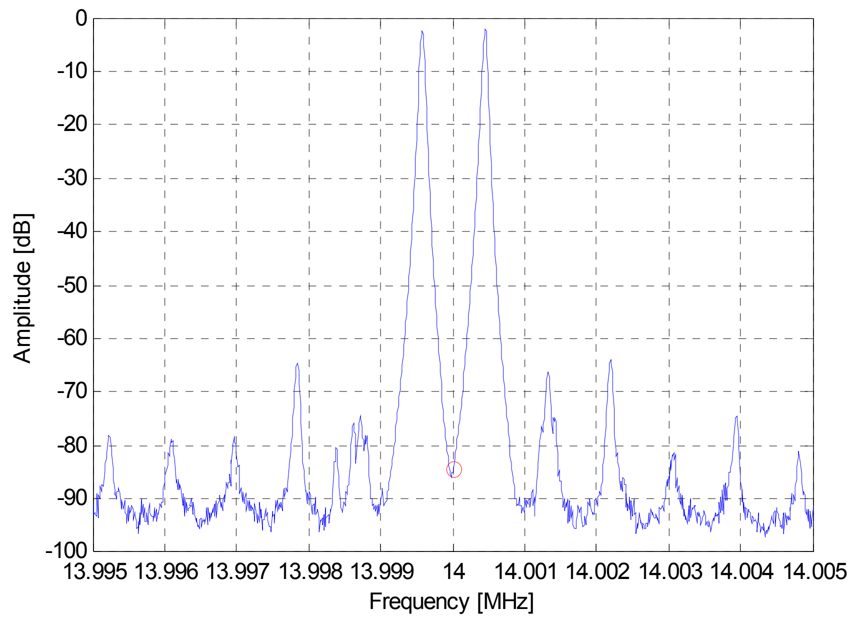
Compensated Amplitude Response

Spectrum of Output Signal without and with Adaptive Predistortion

2-Tone Modulation with 1100Hz and 1900Hz Test Tones



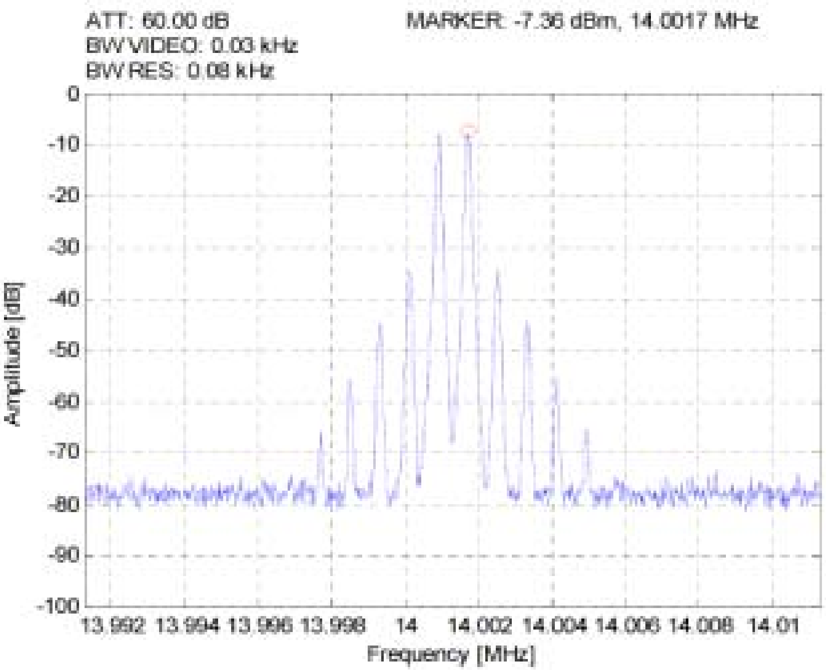
without predistortion



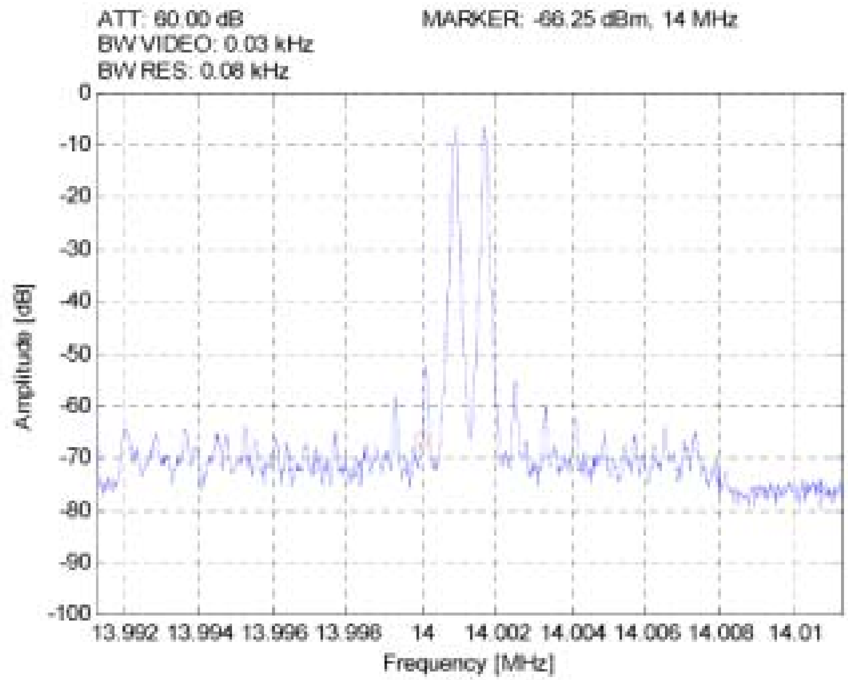
with predistortion (optimally tuned)

Spectrum of Output Signal without and with Adaptive Predistortion

2-Tone Modulation with 1100Hz and 1900Hz Test Tones

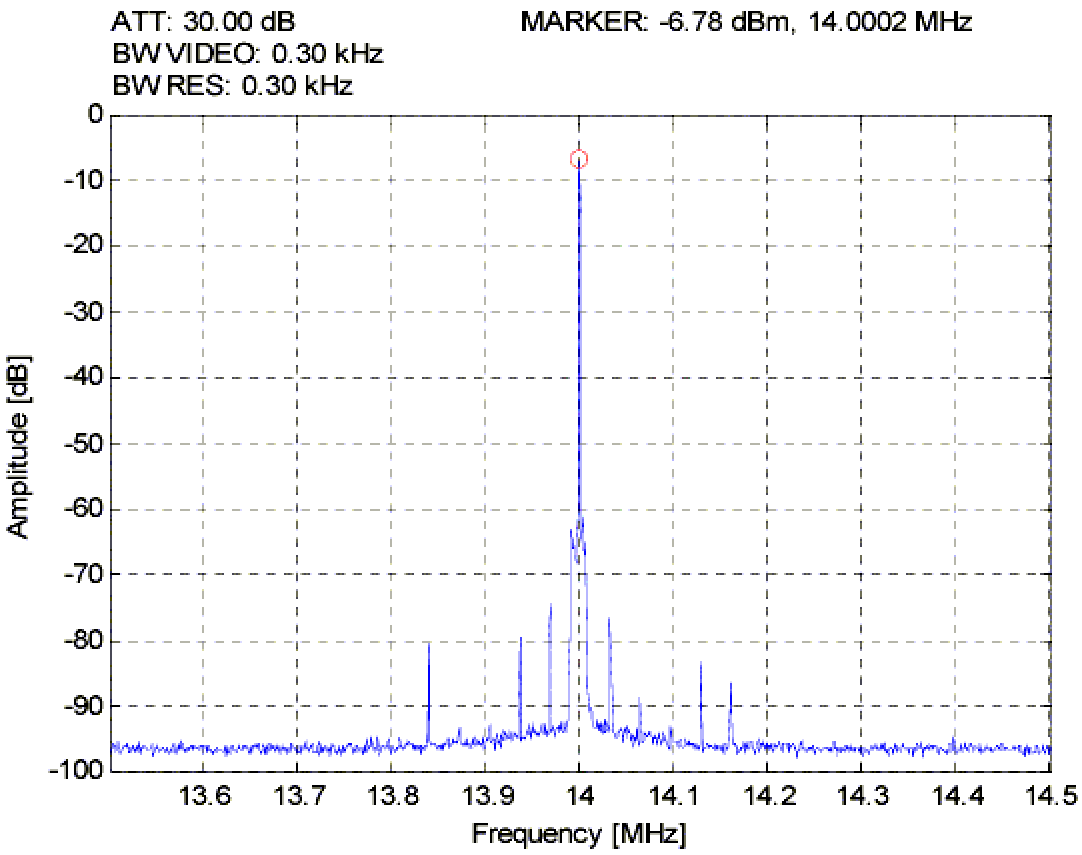


without predistortion

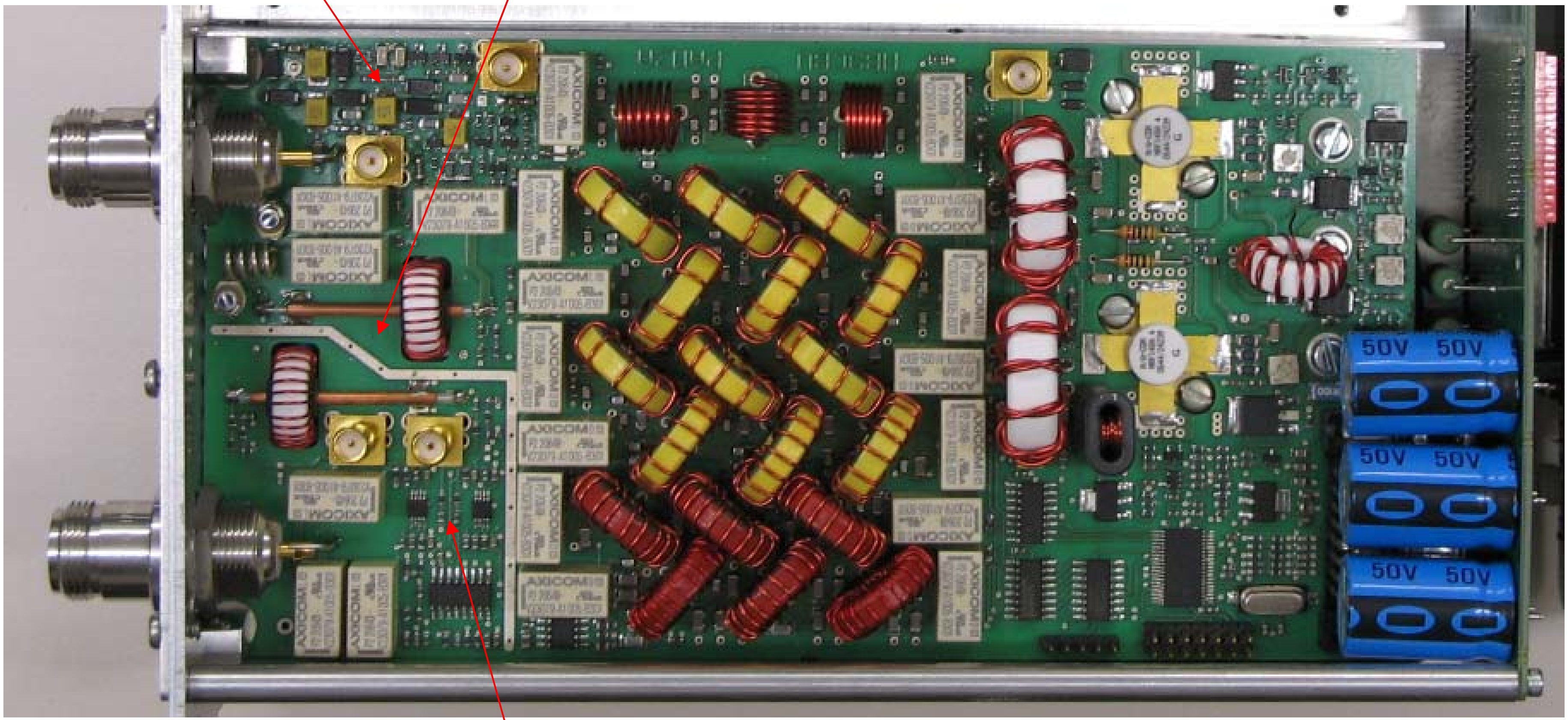


with wideband predistortion

Transmitted spectrum measured over 1 MHz



The Power Amplifier Module PAM2A



Functional Blocks of ADT-200A

Specifications of PA:

Max. Output Power	50W
Min. Output Power	100mW
Spurious and Harmonics	>70dBc

Extras:

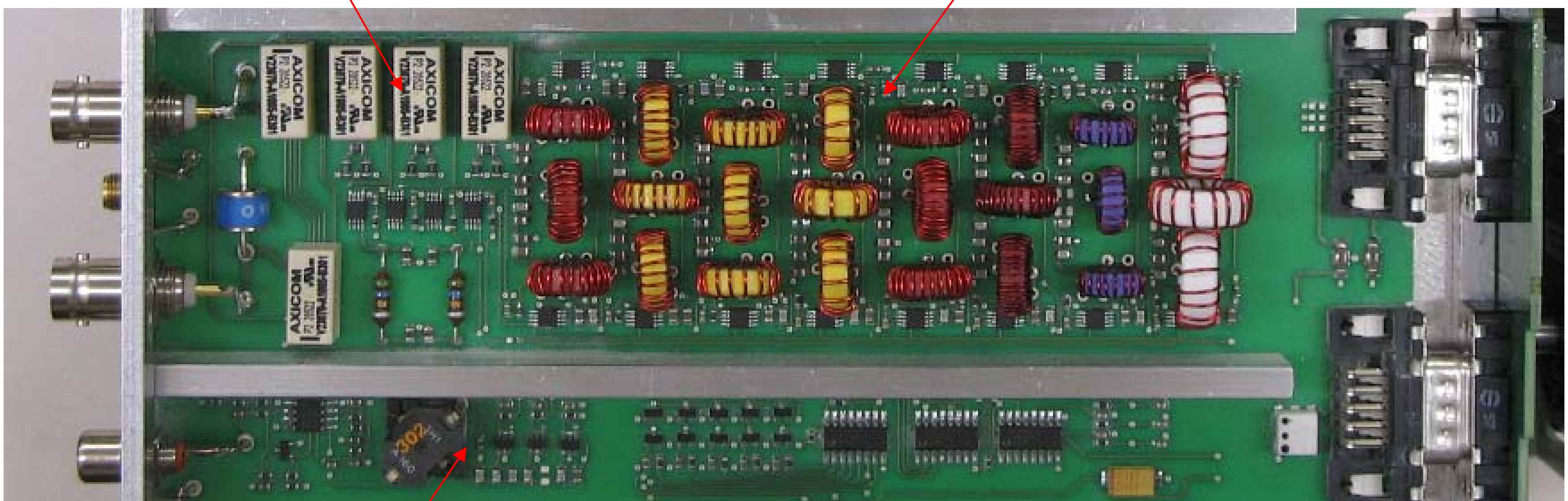
- Adaptive Predistortion
- Power-Meter for full Range of 0.1 ... 50W
- VSWR-Meter with high Dynamic even for 0.1W
- Antennascope determines the complex impedance of an Antenna, either on the TRX or on the Feed Point (optional)

Functional Blocks of ADT-200A

The Preselector

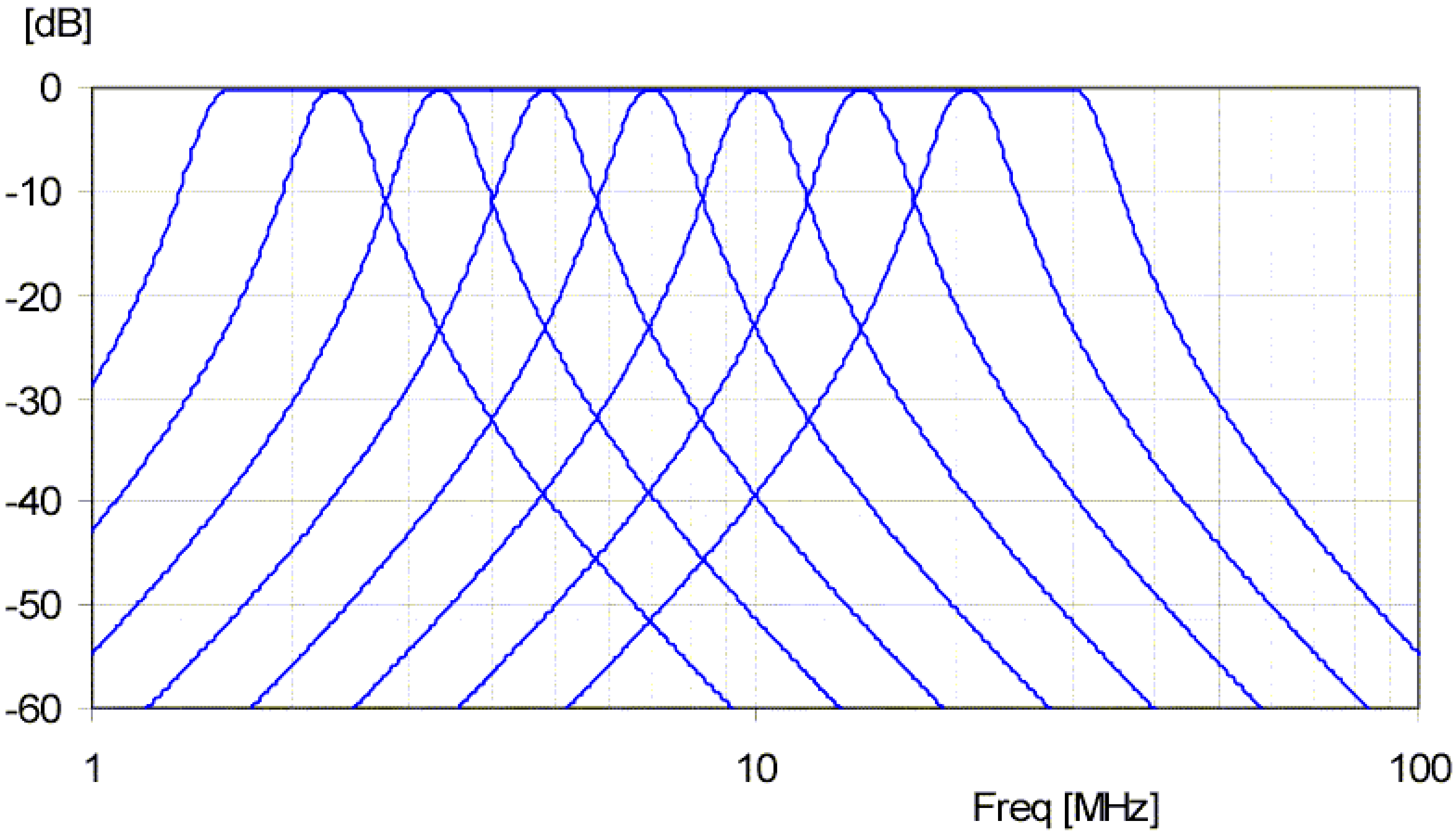
Attenuator, 0...35dB
in 5dB-Steps

Half Octave Filters,
switched by High
Current FET's



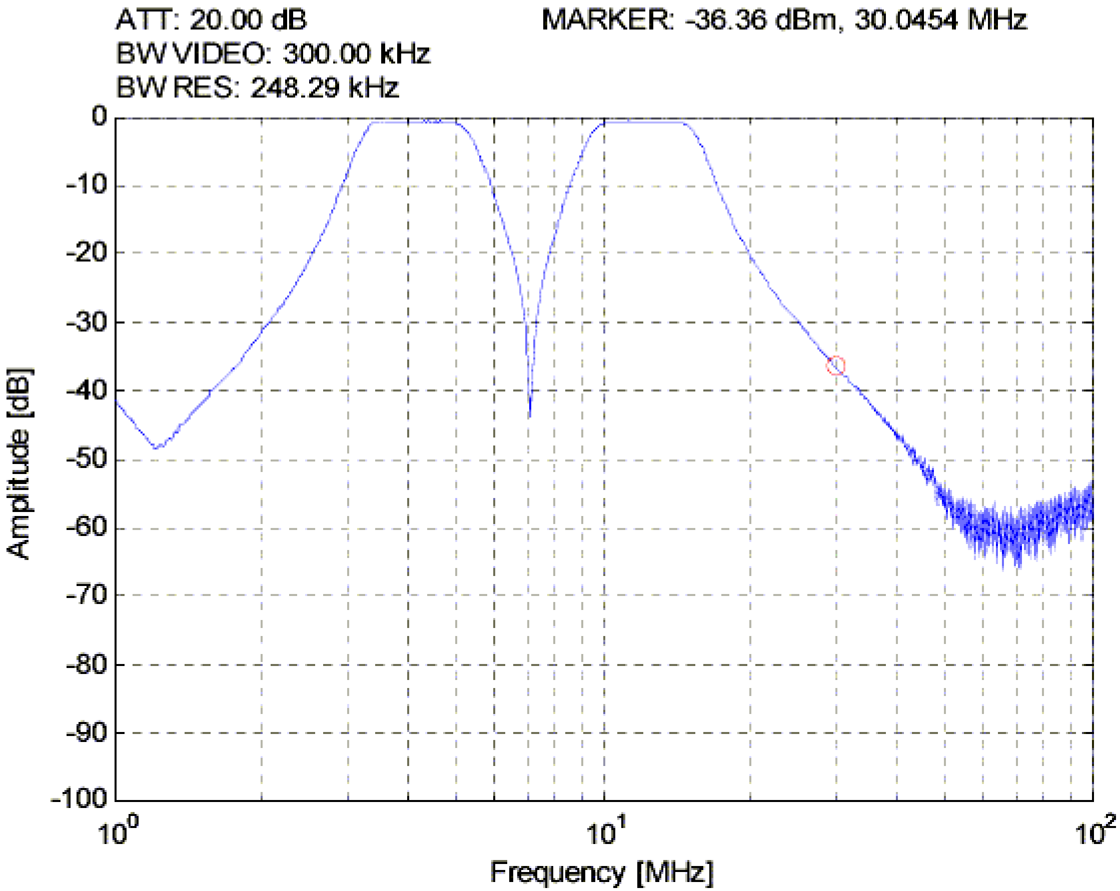
VLF-Front End, for 60, 75,
77.5 and 137kHz

The Half-Octave Filters in the Preselector



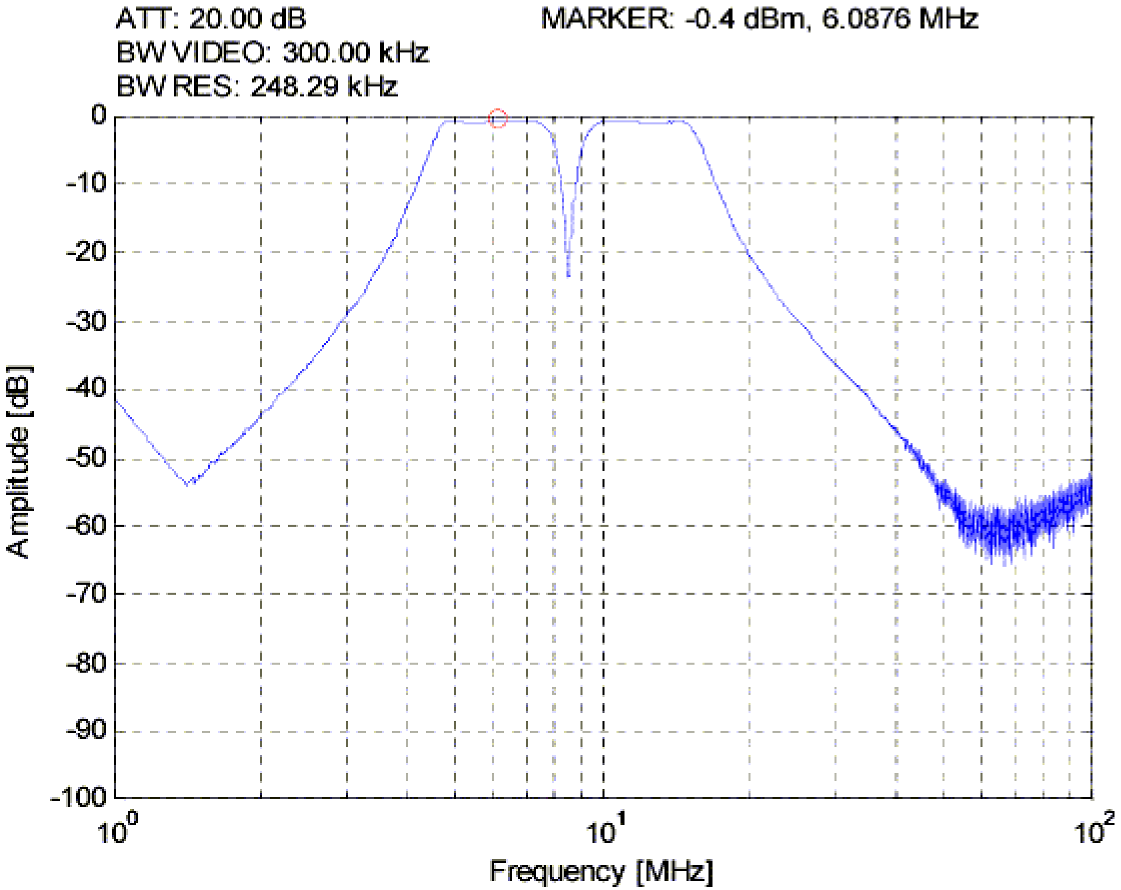
The Preselector

Simultaneous reception in the 80m and 30/20m bands



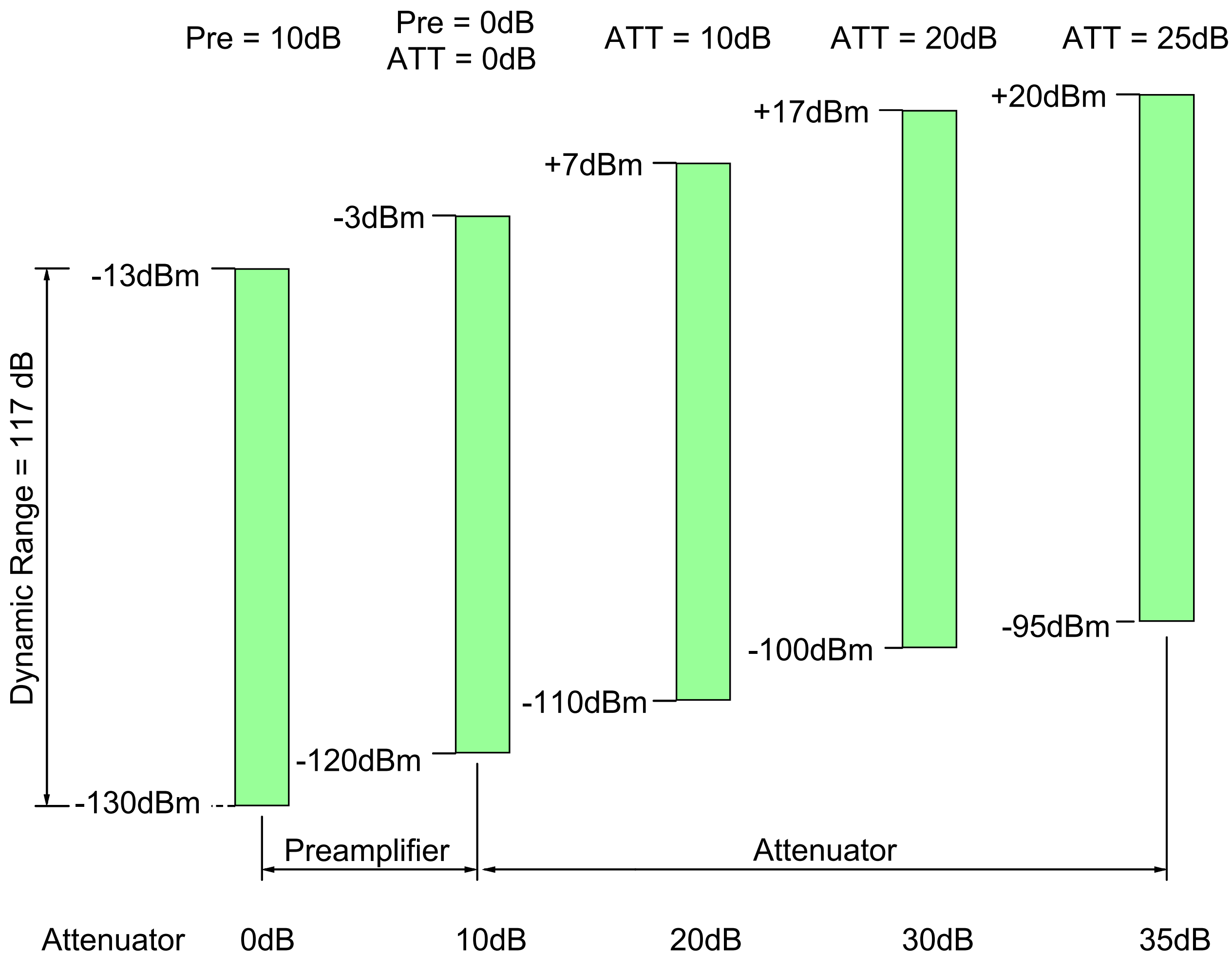
The Preselector

Simultaneous reception in the 40m and 30/20m bands

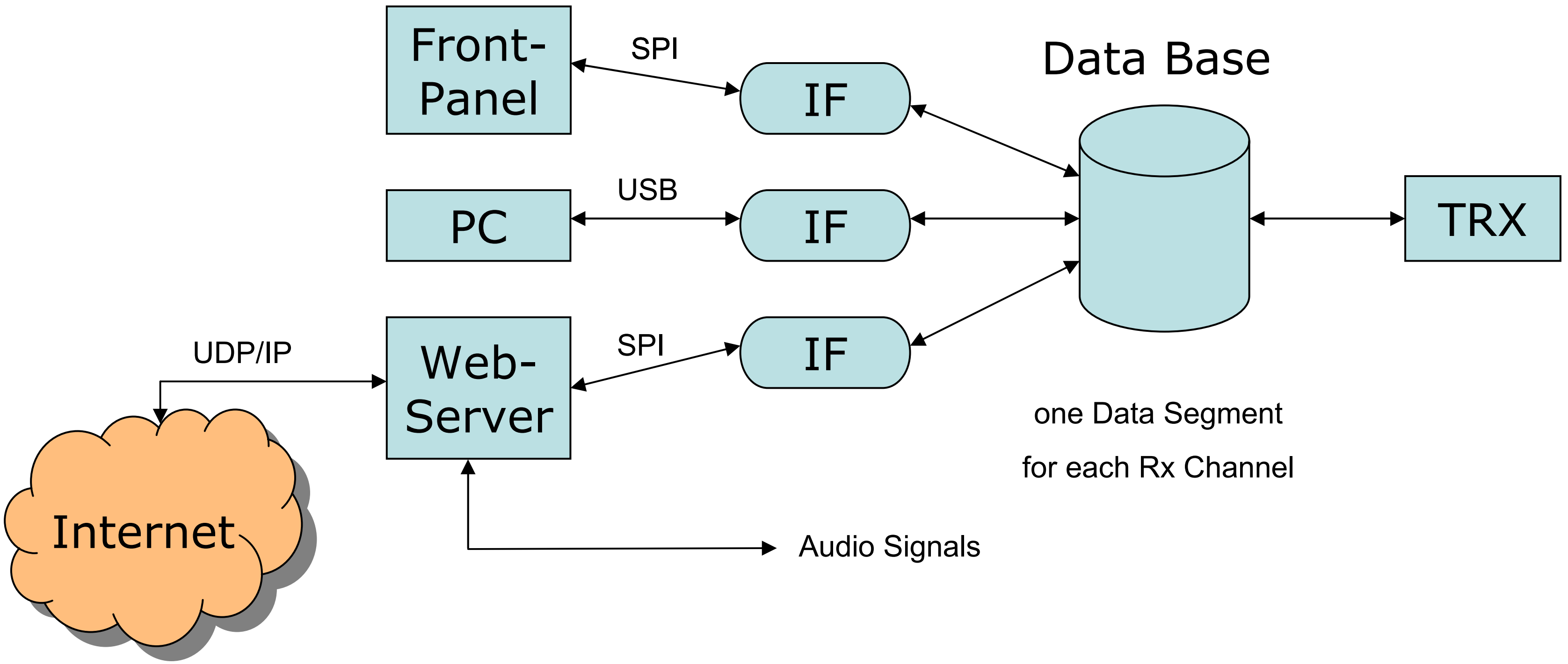


Functional Blocks of ADT-200A

Concept of Input Attenuators



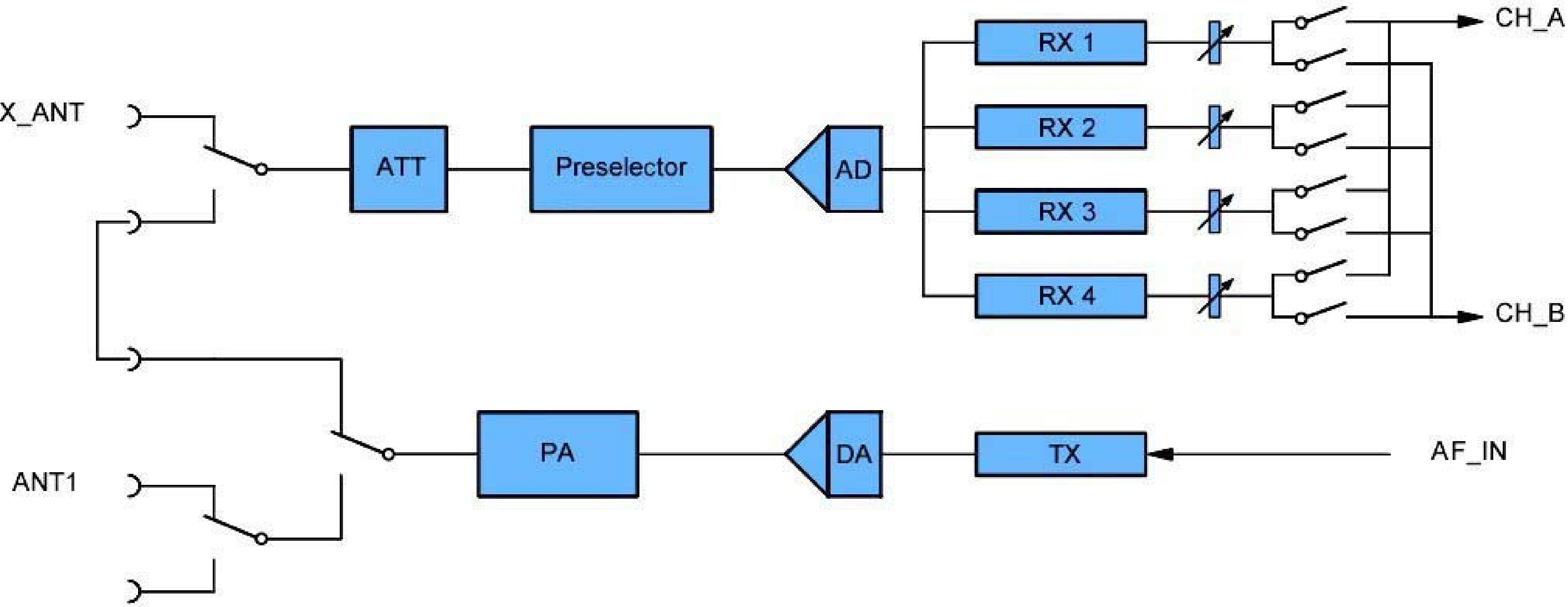
The Concept of Transceiver Control



The Concept of Transceiver Control

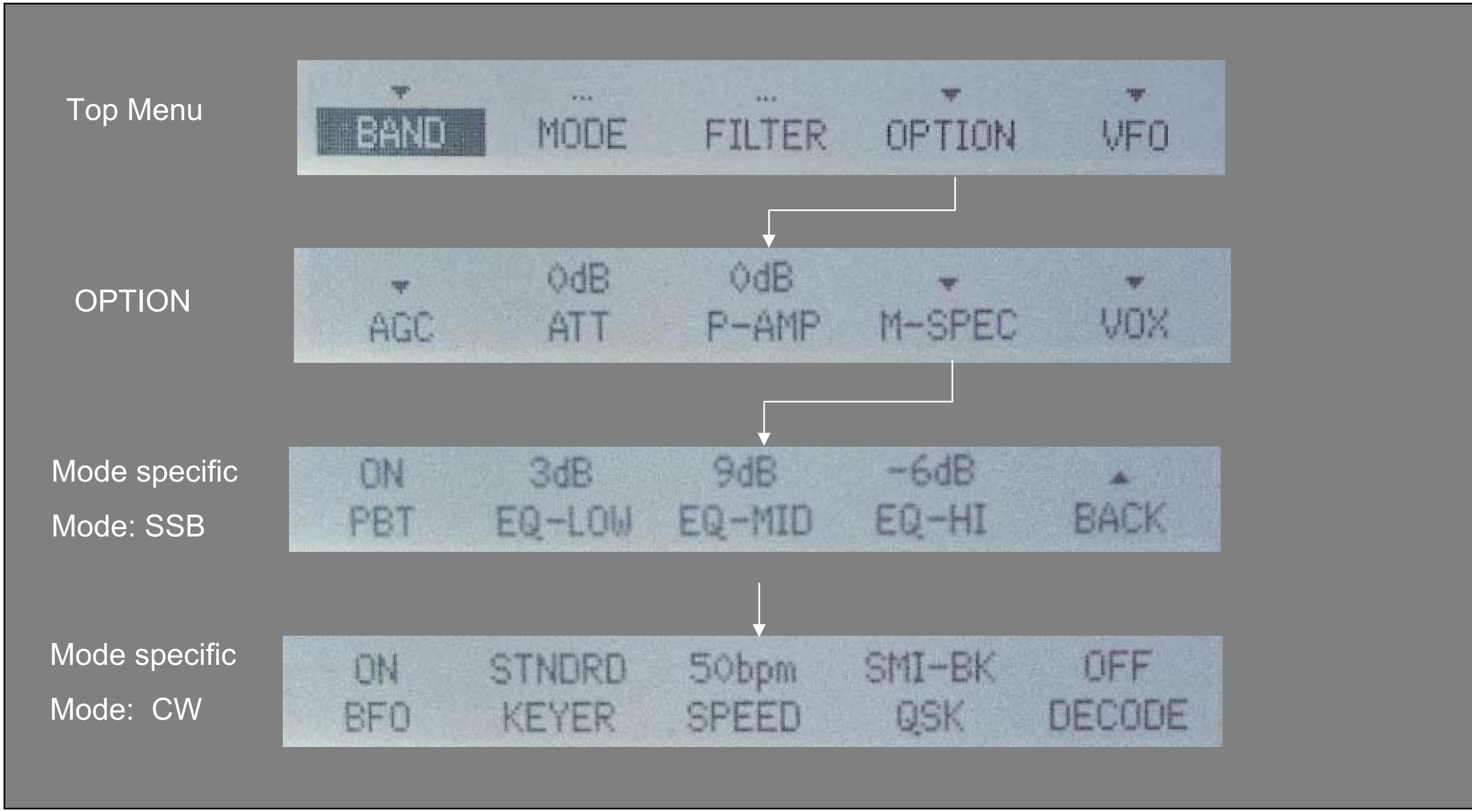
VFO	Function Keys	Tuning Knob	AF Gain Control
VFO 1	Configuration Set 1	Rx1 Frequency (VFO1)	Rx1 Volume
		Tx1 Frequency (VFO5)	TX1 Sidetone
VFO 2	Configuration Set 2	Rx2 Frequency (VFO2)	Rx2 Volume
		Rx2 Frequency (VFO6)	TX2 Sidetone
VFO 3	Configuration Set 3	Rx3 Frequency (VFO3)	Rx3 Volume
		Rx3 Frequency (VFO7)	TX3 Sidetone
VFO 4	Configuration Set 4	Rx4 Frequency (VFO4)	Rx4 Volume
		Rx4 Frequency (VFO8)	TX4 Sidetone

The Concept of Transceiver Control

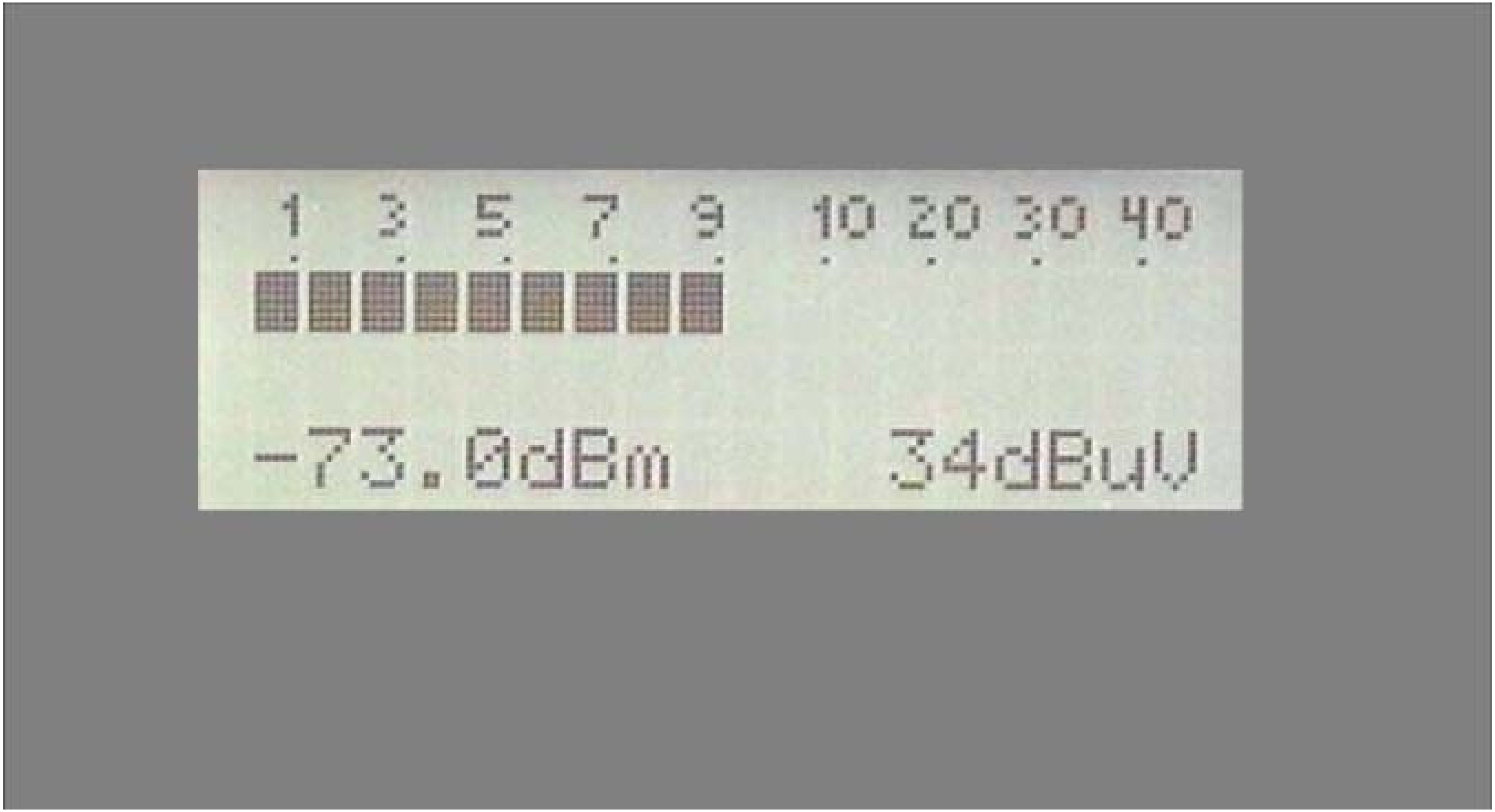


The Concept of TRX Control

The Menu Structure



The Menu Structure



Where do we go from here?

Availability of first units: from January 08

ADT-200 price: approx. CHF 4500 (USD 3800)

Optional add-on features:

- Antennascope
- Web-server module for web-based remote control of an ADT-200A
- User interface for control via a PC
- Spectrum analysis
- 2m/70cm transceiver module with $P_o \approx$ 10W on each band
- Diversity reception