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German WW2 Radio

technology, equipment & innovations

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Scope of presentation



- **Component and packaging technology**
- **Design features**
 - ◆ **Frequency stability & repeatability**
 - ◆ **Maintainability**
- **Typical components**
- **Luftwaffe: MF/HF & VHF communications**
- **Joint Service: E52 'Köln' HF Receiver**
- **Wehrmacht: Portable VHF Tactical Radio**

Highlights of German WW2 military radio



- German radio industry (1930 – 1945) was extremely innovative
- Many advances in component, circuit & system design are still in use today
- Particular strengths in vacuum tubes, receivers and airborne radio systems
- Mechanical construction & packaging generally superior to comparable Allied equipment
- Pioneered deployment of tactical VHF comms (*and even SSB in fixed installations*)

Component and packaging technology



- Use of as few tube types as possible
 - ◆ Simplify manufacture and logistics, but complicate circuit design
- US control of Brazilian quartz markets influenced design:
 - ◆ Simple MOPA-type transmitters
 - ◆ Limit use of quartz crystals to IF filters
 - ◆ Stable tunable oscillators became a fine art
 - ◆ Coils on ceramic formers with silver windings vacuum-deposited onto grooves in former. $Q > 500!$
 - ◆ IF coils on powdered-iron pot-cores
 - ◆ Temp. coefficient of ceramic compensated for that of metallic windings; also NTC and PTC ceramic capacitors
 - ◆ Precision tuning capacitors; plates machined from single billet on ceramic shaft
 - ◆ Solid die-cast light-alloy chassis; heat-producing components thermally coupled to chassis [Link](#)

Design for frequency stability & repeatability



- Large, directly-calibrated tuning dials
 - ◆ resolution to 100 Hz
 - ◆ precision backlash-free dial drives
- Crystal calibrators in some sets
 - ◆ also portable, plug-in calibrators
- Dynamic compensation of transmitter MO (VFO)
 - ◆ RF current & TC/loss factor of capacitor adjusted such that key-down RF heating of capacitor offsets drift due to RF heating of coil and heat-related inter-electrode capacitance changes in MO tube
- Typical stability: $\pm 3.2 \times 10^{-4}$ (± 1.3 kHz at 4 MHz)
 - ◆ for -50 to +50°C, 22 to 29V DC supply voltage range
- This technology was lost in the post-war years
 - ◆ synthesizers removed incentive for its retention

Design for maintainability



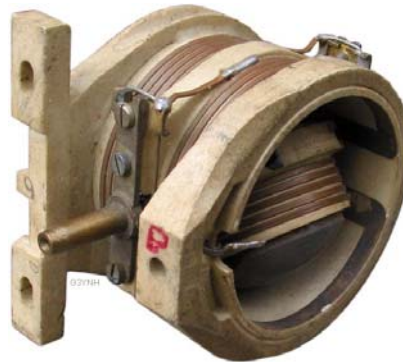
- **3-dimensional construction**
 - ◆ compartmentalized die-cast light-alloy chassis, with each functional circuit in its own shielded compartment wherever possible
 - ◆ tubes in recessed sockets, removable from chassis exterior
- **Compact modular design, with standard interfaces**
 - ◆ inter-modular connectors allowed easy assembly and disassembly
- **Logical breakdown: “block diagram in hardware”**
 - ◆ RX: RF/mixer, LO, IF & selectivity, demodulator, AF
 - ◆ TX: MO, buffers if any, PA, output tank, T/R switching
 - ▶ AM modulator separate
- **Testability**
 - ◆ each module tested individually on special test jigs prior to integration and final test
 - ◆ “BITE”: in-circuit tube check with built-in meter or plug-in test set

Typical components



- **RV12P2000 Pentode:** widely used as small-signal RF, IF and AF amplifier etc. This is the **only** tube type used in the FuG 10 EK and EL receivers, and in the Telefunken E52 'Köln' HF receiver.

- **Variometer:** variable inductor used in FuG10 airborne MF/HF transmitter. L_{min} with coils 90° apart. Note sputtered-on windings.
- Image courtesy G3YNH.



- **RL12P35:** Transmitting pentode used as PA and driver in many radio systems incl. FuG 10. 35W anode dissipation.



- Here are a few examples of components used in German WW2 radio equipment.

FuG 10 (Funkgerät Typ 10)

Luftwaffe MF/HF radio system



- **Developed by Lorenz AG (now Alcatel-SEL), 1936-37**
 - ◆ standardized in 1939 for all larger aircraft with crew > 2
 - ◆ RAF equivalent was T1154/R1155; US equiv. was BC-375/BC-348
- **Plug-in modular component units on flight deck**
 - ◆ EK (HF) & EL (MF) receivers [Link 1](#) [Link 2](#)
 - ◆ SK (HF) & SL (MF) transmitters [Link 3](#)
 - ◆ Antenna control unit (FBG.3), modulator (TZG 10), switchbox etc.
- **Remote ATU (AAG.2) – mounted in tail area, near antennas**
 - ◆ Controlled from FBG3 via sychros, connected to TX/RX via 60Ω coax
- **Basic specifications: [Link 4](#)**
 - ◆ Freq. range: MF 300 - 600 kHz. HF 3000 - 6000 kHz.
 - ◆ Power output: 70W (A1A), 40W (A2A, A3E)
 - ◆ Sensitivity: 4 μV for 10V_{rms} output in 4 kΩ (A1A)
 - ◆ Selectivity: 6 dB BW = 3 kHz, 60 dB BW = 18 kHz
 - ◆ Primary DC power input: 800W max.

FuG10 Overall System View



Module Dimensions:

RX: 180mm H X 200mm W X 220mm D

TX: 220mm H X 215mm W X 200mm D

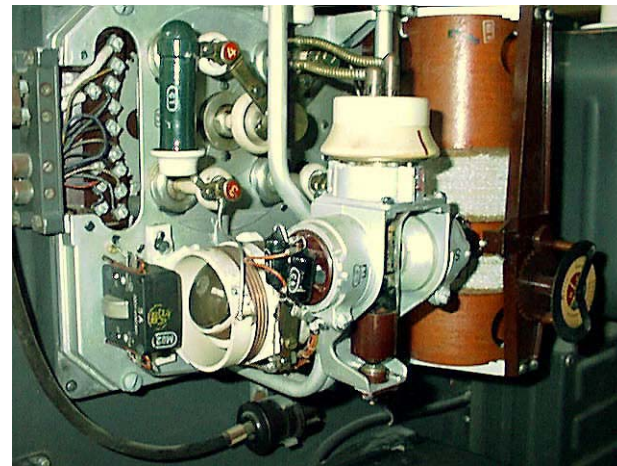


- Upper row: MF RX (EL), HF RX (EK), Antenna Control Unit (FBG.3)
- Lower row: MF TX (SL), HF TX (SK), Switchbox
- 2 antennas: fixed or trailing-wire, selectable at FBG.3. Trailing antenna is remote-controlled (12m HF, 70m MF).
- 60Ω coax between TX/RX and remote ATU. Vacuum T/R relay in ATU.

FuG10 Interior Views



SK Transmitter with RL12P35 tubes
(1 in MO, 2 in parallel for PA)
Image courtesy LA6NCA



AAG.2 ATU showing HF variometer (left),
vacuum T/R relay (centre) and MF
variometer (right). Image courtesy SRS

- **Note the extremely high quality and finish.**

FuG10 Interior Views

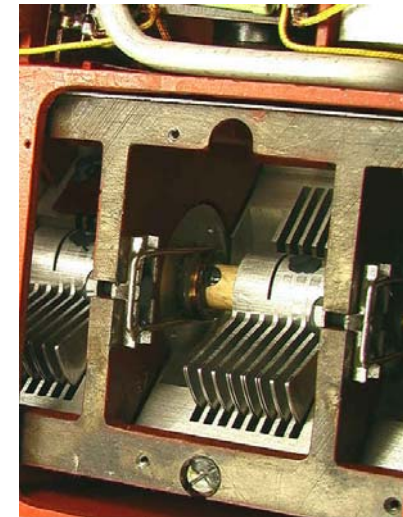


EK Receiver, top view, showing tube sockets, IF transformers and chassis compartments.

Image courtesy Bo Samuelsson



EK front panel frame & tuning dial mechanism with 4 preset cams.
Image courtesy LA6NCA



EK: Detail of main tuning capacitor.

Image courtesy LA6NCA

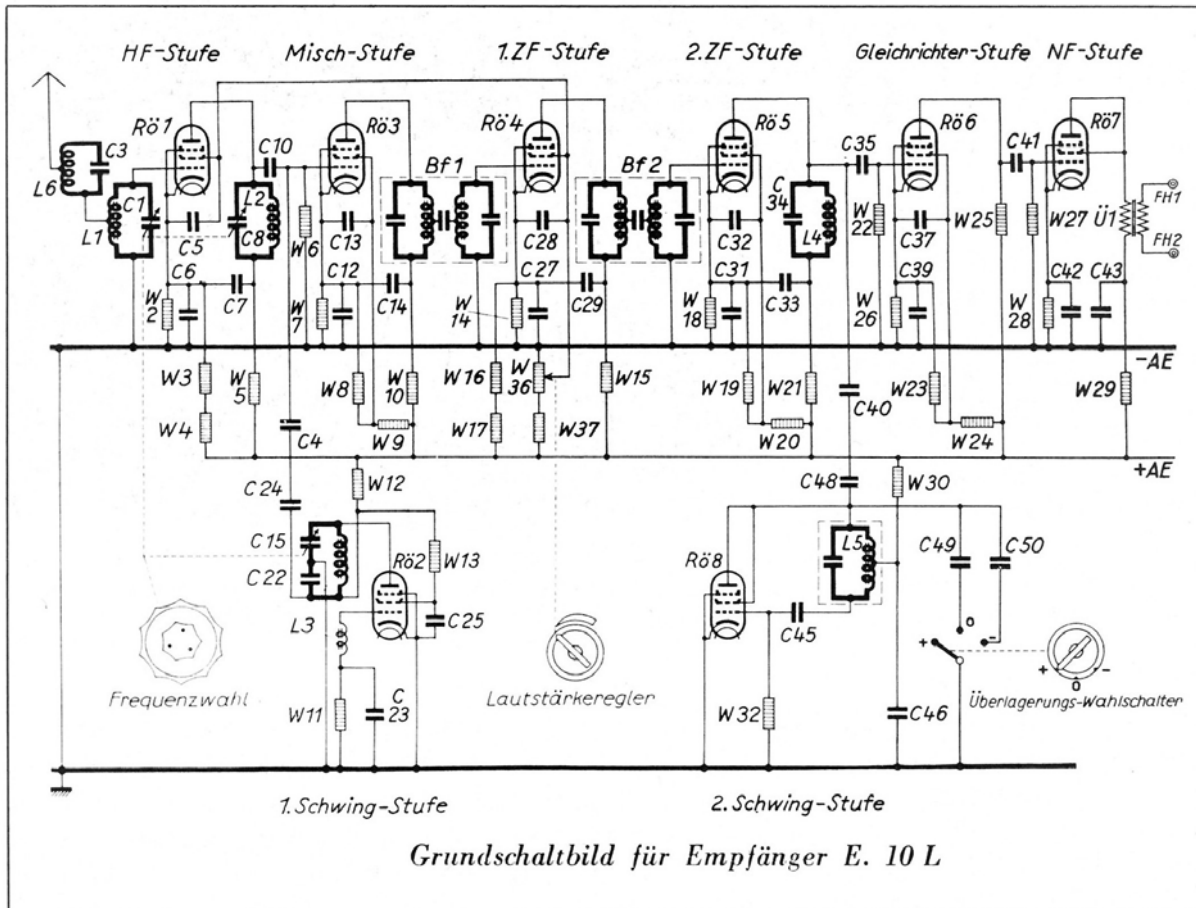
- **Note the extremely high quality, precision and finish.**

Basic Schematic of E 10 L MF Receiver (300 - 600 kHz)

Source: Fritz Trenkle



Note: No AGC in E 10 L. Later HF RX E 10a K had AGC circuit.

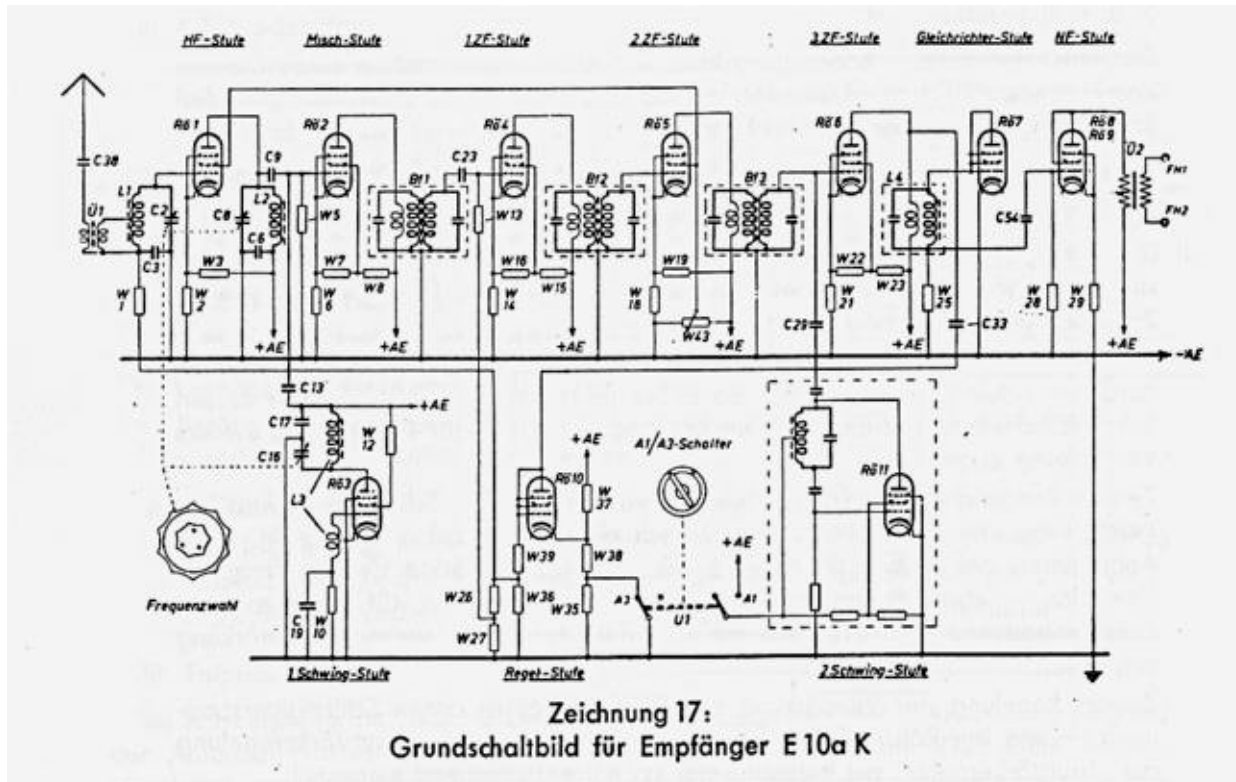


Basic Schematic of E 10a K HF Receiver (3000 - 6000 kHz)

courtesy Bo Samuelsson

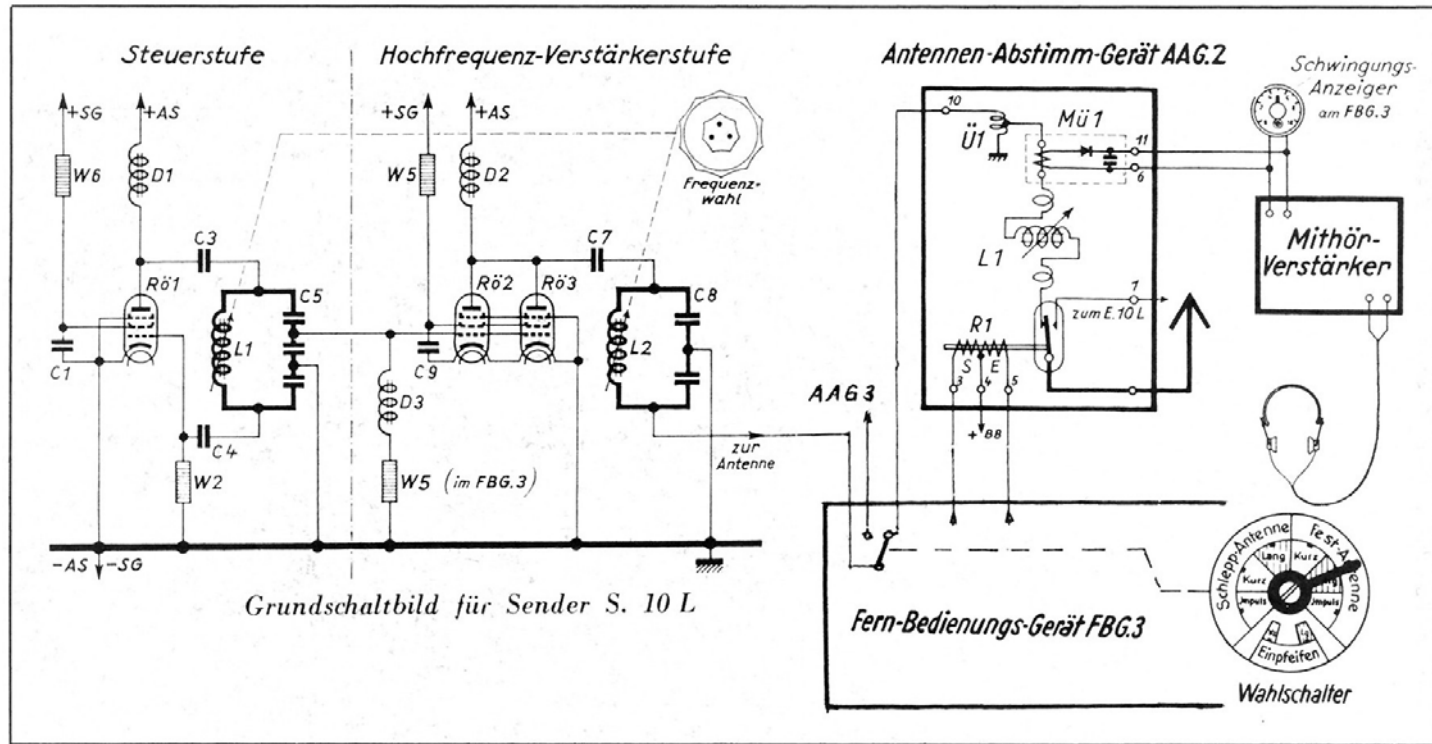


Note: R610 is AGC circuit. "10a" denotes AGC.



Basic Schematic of S 10 L MF Transmitter (300 - 600 kHz)

Source: Fritz Trenkle



Note 1: Connections from TX and RX via Ant. Control Unit (FBG.3) to ATU (AAG.2) are 60Ω coax.

Note 2: Monitor amplifier (Mithör-Verstärker) and RF power meter (Schwingungs-Anz.) coupled via current transformer Mü1.

Note 3: Later auto-ATU tuned fixed antenna at low power. Matched when rate-of-change of RF current approached zero.

Note 4: S 10 L and S 10 K transmitters used grid-block keying.

Telefunken E52b 'Köln' HF

Receiver - the most advanced RX of its era

Image courtesy Bo Samuelsson

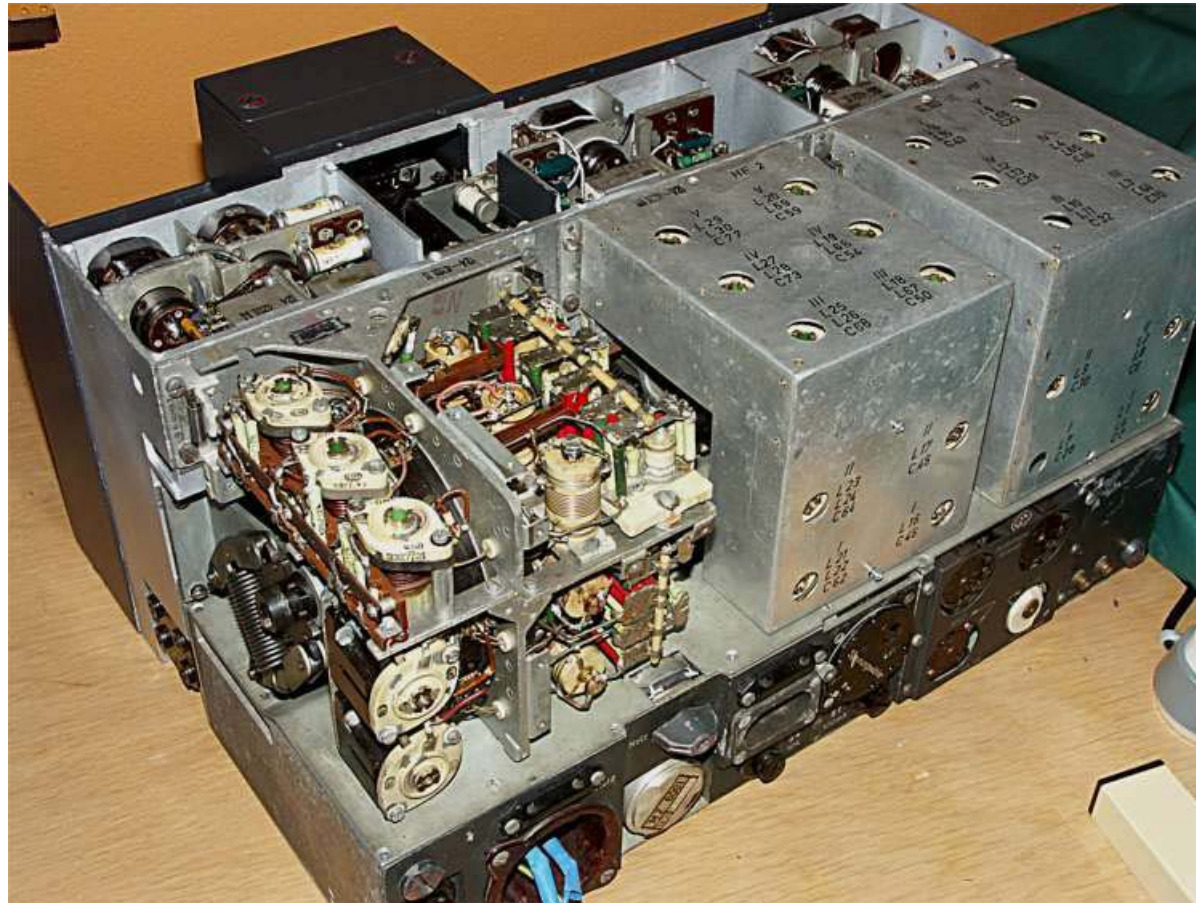


[Link 1](#) [Link 2](#)

E52 'Köln' HF Receiver

Interior View (courtesy Bo Samuelsson)

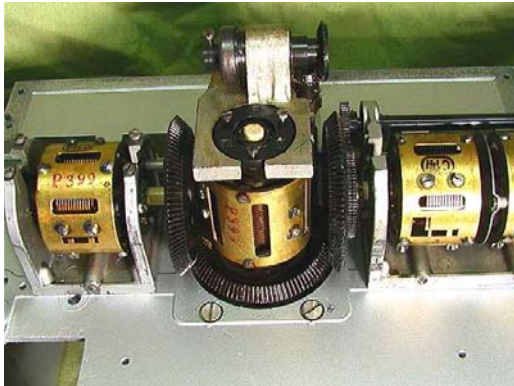
Modules (l-r): mixer/LO (shield removed), RF 2, RF 1



E52 'Köln' HF Receiver

Interior Details (courtesy LA6NCA)

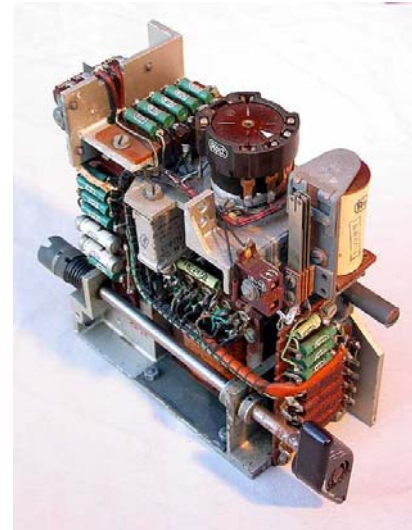
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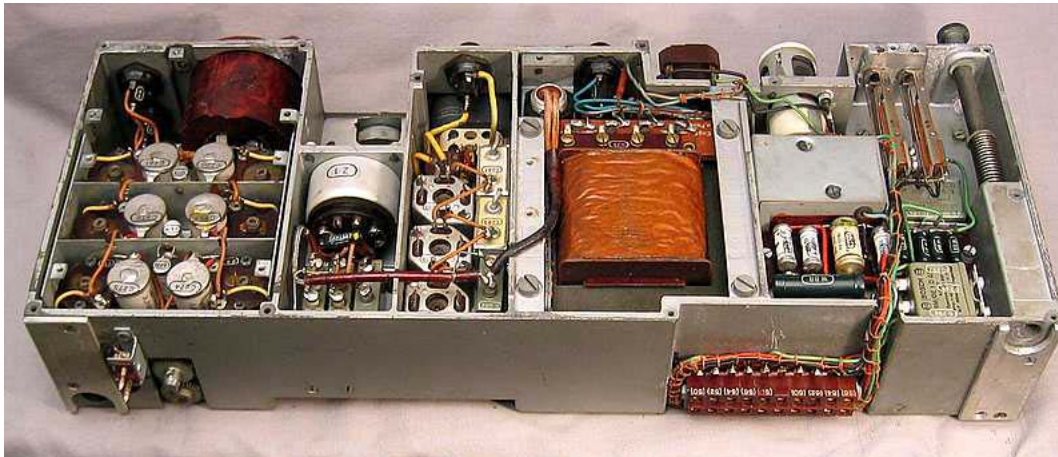
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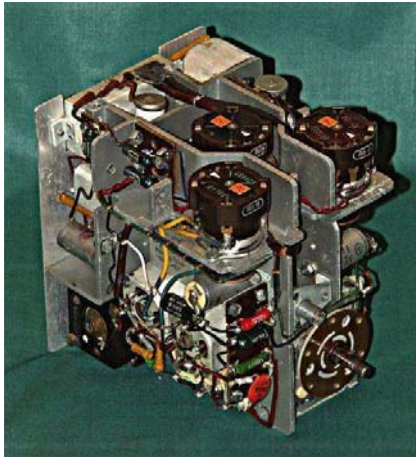


- 1 Tuning capacitor detail
- 2 IF/crystal filter module
- 3 AF amplifier module
- 4 Mains/12V PSU module

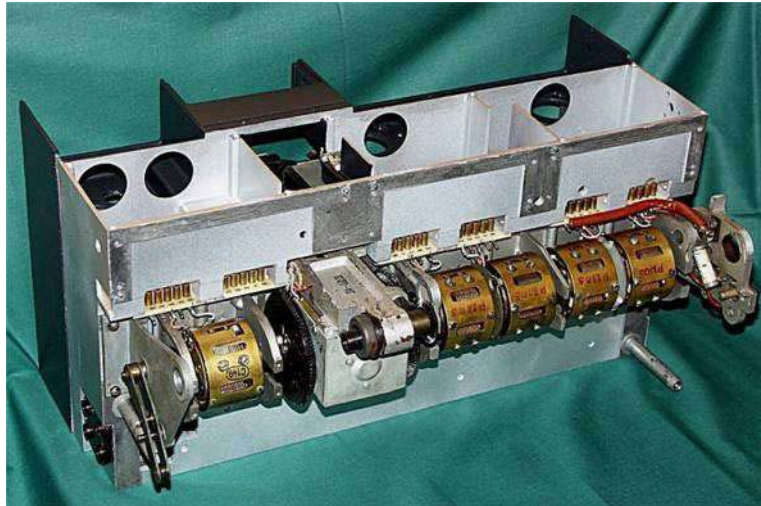
E52 'Köln' HF Receiver

Module Details (courtesy Bo Samuelsson)

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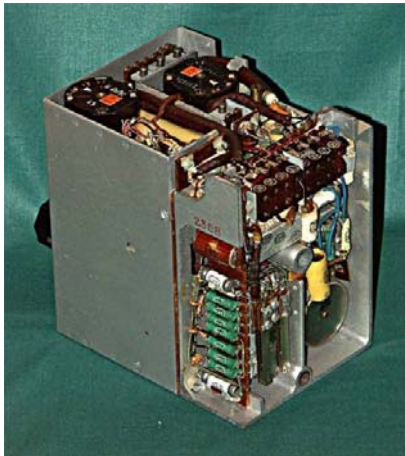


3



- 1 IF/crystal filter module
- 2 BFO module
- 3 Main tuning capacitor
- 4 Tuning dial detail

2



4



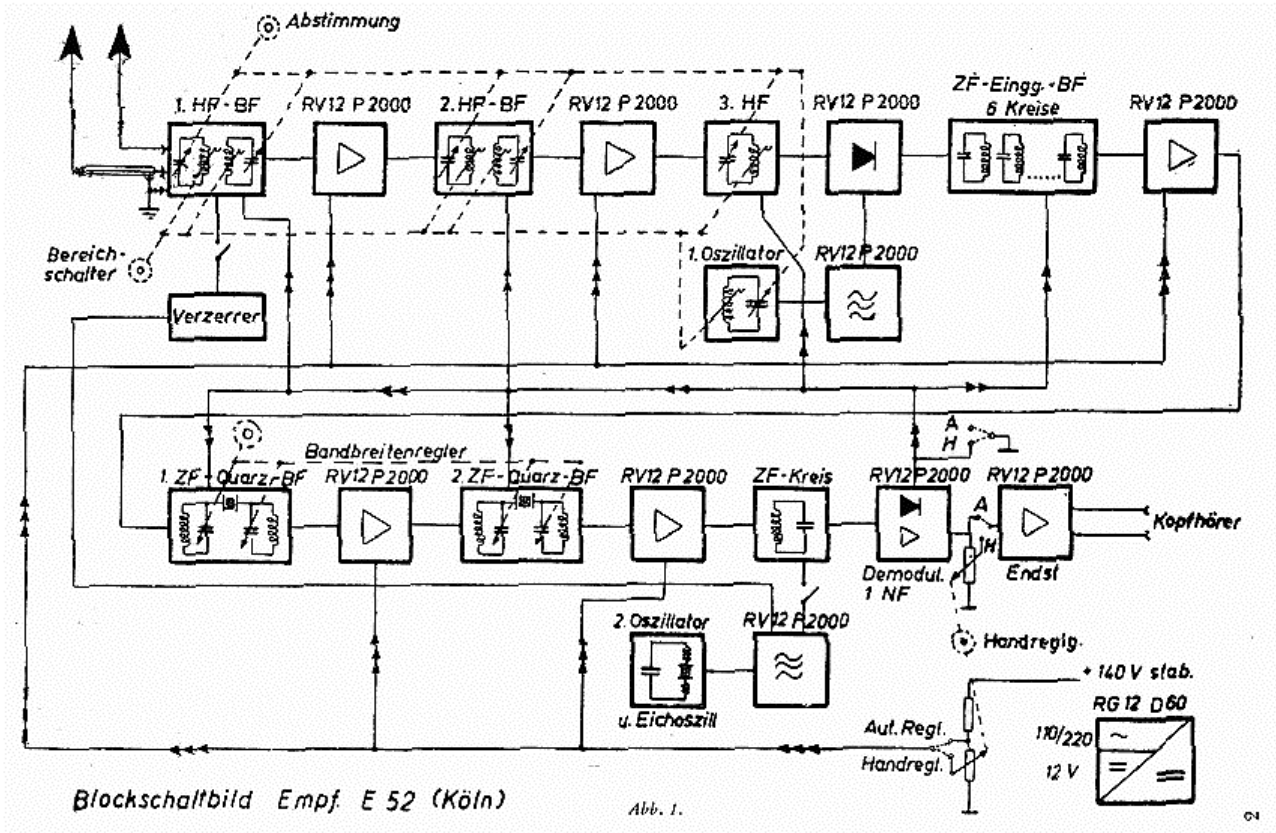
E52 'Köln' HF Receiver



- **Single-conversion HF superhet communications receiver**
 - ◆ Developed 1941 by Telefunken for Luftwaffe; adopted later by all services. Used by German merchant marine until early 1960's
 - ◆ 5-pole active tunable RF preselector with 2 RF amps: superb image rejection, IF rejection, front-end protection and sensitivity
 - ◆ 1 MHz IF; crystal filter with continuously-variable bandwidth
 - ◆ Supported emissions: A1A, A2A, A3E
 - ▶ [SSB/ISB adapter](#) available for J3E, B8E
 - ◆ Die-cast chassis with shielded modules plugged into backplane
 - ◆ Unique precision geared tuning mechanism with optical projection readout (window above main dial). Resolution 1 kHz
 - ◆ Motorized tuning drive on E52a version, omitted on E52b
 - ◆ AGC on all RF and IF stages
 - ◆ Crystal-controlled BFO with +900 Hz offset
 - ◆ Built-in power supply for AC mains and 12V DC operation

E52 'Köln' HF Receiver

Block Diagram (courtesy LA6NCA)



E52 'Köln' HF Receiver

Technical Specifications



- **Frequency ranges:** 1.5 – 3 MHz, 3 – 6 MHz, 6 – 10 MHz, 10 – 17.7 MHz, 17.6-25.2 MHz
- **Modes:** A1A, A2A, A3E. Optional F3E, J3E, B8E
- **Power requirement:** 110-230VAC 50-60Hz, or 12VDC
- **Dimensions:** 245 x 446 x 350 mm
- **Weight:** 40.8 kg
- **Sensitivity:** A3E (wide) 3.5 μ V; A1A (wide) 1 μ V; A1A (narrow) 0.3 μ V
- **Image rejection:** > 94dB at 20MHz
- **IF rejection:** > 100dB at 1.5 MHz
- **Antenna inputs:** 60/150 Ω
- **IF:** 1000 kHz
- **BFO:** 1000.9 kHz
- **Bandwidth:** continuously variable from 10 kHz (-3dB)/*26 kHz (-60dB)* to 200 Hz (-3dB)/*4 kHz (-60dB)*
- **Frequency stability:** < 30 x 10⁻⁶ per °C
- **Tuning dial resolution:** 1 kHz

Mobile VHF Tactical Radio



- German and Dutch radio industries had found VHF line-of-sight (LOS) propagation ideal for urban mobile radio comms. [Link](#)
- This led to VHF R/T systems in the 27 - 55 MHz band – rapidly adopted by Wehrmacht and Luftwaffe in late 1930's.
 - ◆ "Equipping armoured troops with VHF radio enabled individual units to be tied into the command network. The control over fast-moving combat forces gave the army operational advantages."
- Tactical VHF radio was the “central nervous system” of the Blitzkrieg
 - ◆ Allowed integrated command and control of infantry, armour and close air support
- Mobile VHF transmitters had 10 to 15W output
 - ◆ portables such as "Kleinfunksprecher d" (1944) had 0.25 to 0.5W output [Link](#)
- Frequency ranges 20 - 33 & 30 - 55 MHz; A3E emission (AM)
 - ◆ US Army deployed 27 - 55 MHz F3E (FM) tactical radio only in late 1943/early 1944
- British Army resisted VHF adoption almost until war's end
 - ◆ “NIH factor” and concerns about LOS propagation in congested areas were obstacles
 - ◆ Low-power AM radio sets in 2 – 4 MHz range with short antennas contributed to disastrous comms. breakdowns (e.g. “Market Garden”)

Portable VHF Tactical Radio: *Kleinfunksprecher d "Dorette"*

image & data courtesy LA6NCA



KIFuSpr.d Specifications

Frequency range: 32 – 38 MHz

Power output: 200 mW

Power input: 1.4V, 150V

Battery life: 25 hrs. (80% RX, 20% TX)

Antenna: Tape antenna, 1.6m long

Tubes: Two RL 1 P 2, one DDD25

Size, transceiver: 130 x 70 x 200 mm

Size, battery box: 110 x 100 x 170 mm

Weight, transceiver: 1.6 kg

Weight, battery box: 1.5 kg

Portable VHF Tactical Radio: Kleinfunksprecher d "Dorette"

images courtesy LA6NCA



Above: Interior view, showing tuning dial
Left: Side view. Note tuning dial window

Future Presentations on German WW2 RF Topics



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- **COMINT/SIGINT:** Intercept receivers & test equipment (*e.g. spectrum analyzers!*)
- **ECM:** Comms and radar jamming, ECCM
- **Radar systems:** Ground, airborne and naval

Links for further study



- [Helge Fykse LA6NCA Website](#)
- [Bo Samuelsson's Vintage Radio Site](#)
 - ◆ *Sincere thanks to Helge and Bo for graciously allowing me to use their superb photos*
- [LA8AK Radio Communications Resource Page](#)
- [Foundation for German Communications](#)
- [VA7OJ/AB4OJ Military Radio Page](#)
 - ◆ Also see [Military Radio Links](#)