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German WW2 SIGINT/COMINT

radio interception, signal analysis and direction-finding

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VA7OJ

Scope of presentation

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- Radio interception & surveillance
  - Equipment: receivers & antennas
  - Techniques
- Signal analysis
  - Manual baseband processing
  - *Wellenanzeiger* ***(spectrum analyzers)***
  - Radar signal analysis
- Direction-finding
  - Equipment: receivers, antennas, specialized D/F sets
  - Techniques: fixed, mobile & portable D/F

Intercept & surveillance receivers

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- Fu.H.E. (*Funkhorchempfänger*, radio monitoring receiver)
- 6 versions covering LF/MF, HF, low VHF, high VHF; 75 kHz to 305 MHz.
- HF example: Fu.H.E.u1 (0.75 - 25 MHz)
- Portable, battery-operated superhets using one directly-heated tube type (RV2P800).
- Large, precision 270° tuning dials.
- Frequency stability 3 x 10^{-4} over -20…+40°C and large battery-voltage range.
- Used for interception (and D/F with adapters).

Salient features of Fu.H.E. family

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- Battery-powered: 1 tube type (RV2P800 pentode).
- 1 or 2 RF stages.
- 2 or 3 IF stages with variable-bandwidth crystal filters.
- BFO & crystal calibrator (combined in MF, HF versions; separate in LF version.
- Low VHF version (24 - 61 MHz) had push-pull LO.
- 60 - 150 MHz version had 2 single-tuned RF stages, 5 bandpass IF stages & diode detector; final BPF could be shifted for FM slope-detection.

Telefunken Fu.H.E.c HF Receiver
(3.75 – 26 MHz) introduced Oct. 1939

Front panel
image courtesy LA6NCA

RV2P800 tube with handle

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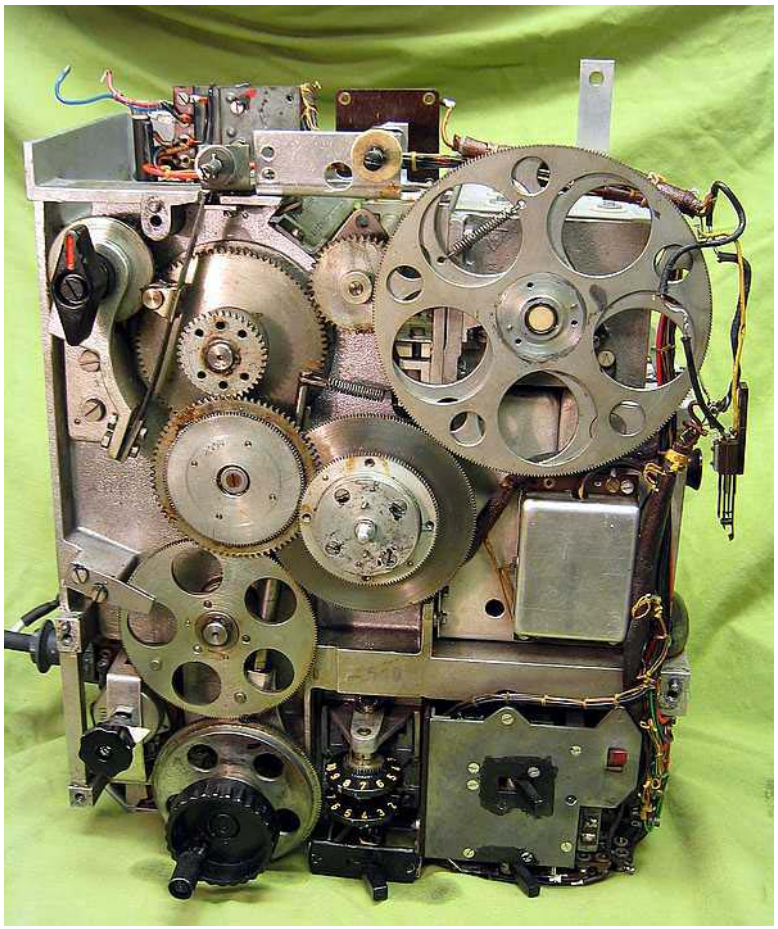
Built-in test meter for battery voltages & tube anode currents *courtesy LA6NCA*

Fu.H.E.c Receiver

interior view & tuning mechanism

(image courtesy LA6NCA)



Frequency ranges:

1. (White) 3.53-5.94 MHz
2. (Red) 5.77-9.68 MHz
3. (Yel) 9.40-15.80 MHz
4. (Blu) 15.35-25.80 MHz

Power requirements:

2V/1.9A, 90V/20mA
Grid bias voltage from anode current.
Converter **EW.h** for 12V operation.

Dimensions:

430H x 340W x 240D mm

Weight:

27 kg

R&S "Samos" VHF/UHF Surveillance Receiver

RD12GA mixer tube

- FuMB 4 "Samos": 80 - 480 MHz. FuMB 5 "Fanö": 400 - 800 MHz. AM/FM.
- Used on board aircraft and U-boats for radar and VHF radio interception.
- Modest sensitivity due to thermionic-diode mixer and lack of RF preamp.
- Typical antennas were rotating dipoles w/azimuth scale, and ground-planes.
- Baseband output fed to oscilloscope for signal analysis, pulse-width measurement etc., and occasionally to headset for R/T monitoring.
- Post-war successor ESD used as field-strength measuring receiver.

R&S ESD VHF/UHF Receiver: interior views

PSU

Front end

Demod

IF strip

Mixer

L.O.

- ESD was post-war successor to “Samos”; range 90 - 480 MHz (AM & FM).
- Used as field-strength and monitoring receiver in broadcast and comms.
- Miniature UHF tubes in front end; German metal tubes in IF, demod, PSU.

Antenna Examples

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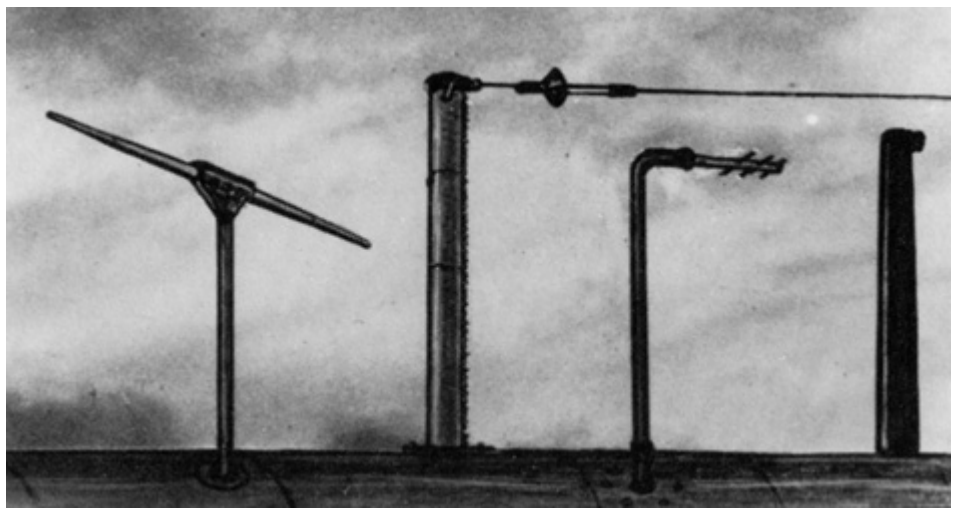
Fu.NP.E a/c
Rotatable loop
0.19 - 25 MHz
Image: LA6NCA

RETURN

SIGINT antennas for FuMB 4/5 receivers *(source: Fritz Trenkle)*
Rotatable dipole Yagi Monopole



Interception Techniques

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- Signal interception & analysis (SIGINT) usually combined with direction finding (D/F).
- Land-based MF/HF SIGINT targeted mainly Allied clandestine agent transmitters & Resistance broadcasters.
- Emphasis placed on locating agent sites, but radio counter-intelligence *(Funkspiel)* later became very refined.
- Mobile and portable D/F-SIGINT units were widely deployed throughout Germany & Nazi-occupied Europe.
- A few reconnaissance aircraft were fitted with VHF intercept receivers covering US Army tactical FM range (27 - 55 MHz FM) after 1943 – but Göring resisted allocation of precious combat aircraft to “silly games”…

Interception Techniques *(cont.)*

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- Identification of traffic source depended heavily on skill of intercept operators.
- Experienced CW ops could identify individual “fist” of clandestine op.
- CW & R/T traffic was often recorded onto tape for off-line analysis, and to build rudimentary database.
- Simple signature analysis via oscilloscope fed from intercept receiver.
- German cryptanalysts worked to “break” Allied telegraph and voice encryption.
- Ing. Meyer at RPZ (Reichspost tech. centre) “cracked” A3 scrambling on Churchill/FDR R/T link; this coup may have compromised plans for 1943 Allied Sicily landings.

German Interception Failures

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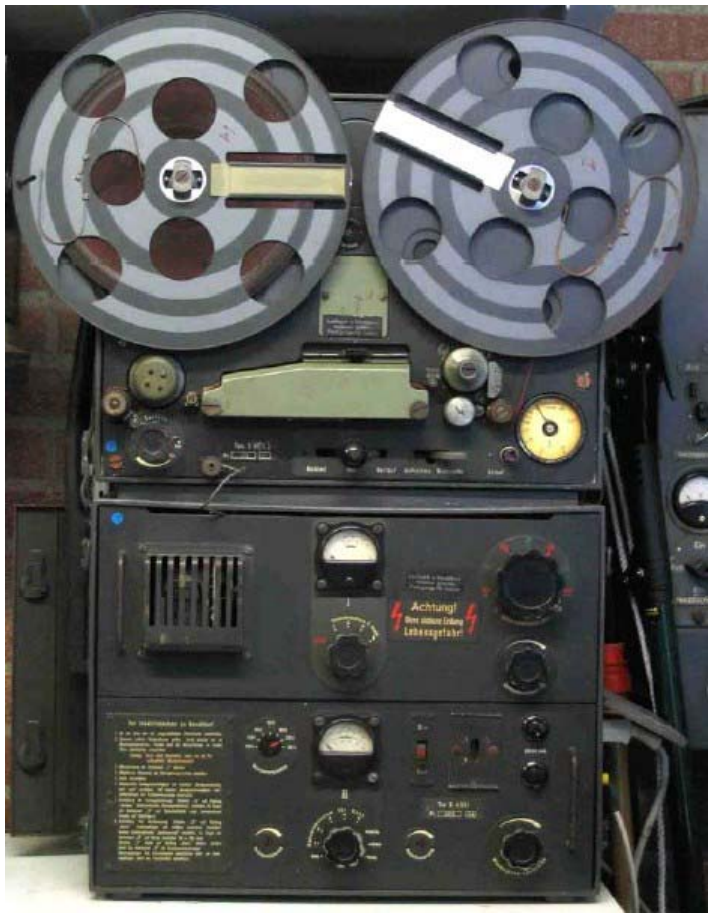
- Hitler & Co. forbade R&D on projects which could not go into series production within 6 months.
- Resulting shortage of VHF/UHF receivers seriously impacted German intercept ability as Allied comms & radar moved ever higher in frequency.
- In mid-1940, a German monitoring site on the Channel coast detected RAF R/T traffic in the 98 - 131 MHz range.
- But until war's end, no SIGINT equipment covering this band (used by RAF, RCAF & USAAF) went into series production!
- R&S “Samos” RX (80 - 480 MHz) was primarily a radar detection receiver; its use for R/T intercept was “discouraged”!
- Allied bombing caused acute shortage of VHF/UHF tubes & other components.

Telefunken Magnetophon
(military version: Tonschreiber b)



- **Tonschreiber b**: introduced 1934-35
- Military version of **Magnetophon**
- Used **BASF** 6.35mm plasticized-paper tape with iron-oxide coating
- **Tape speed:** 9…120 cm/sec
- **AF response:** 50Hz….10 kHz (-6dB)
- Installed at interception sites to record traffic for off-line analysis

Wellenanzeiger (spectrum analyzers)

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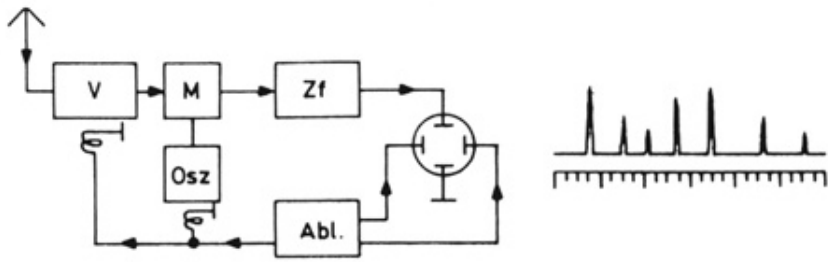
- *Wellenanzeiger* (wave display): rudimentary spectrum analyzer with associated spotting receiver.
- Development driven by need to display multiple signals in frequency/time domain, and capture even very short-duration transmissions.
- Basic HF instrument (1) has wobbulated LO with saturable iron-dust core in LO tank coil. Control winding on tank-coil core.
- Horizontal time-base of CRT drives this control winding.
- Wide RF tuning range (> 2:1) difficult above 100 MHz; motor-driven air capacitors used in RF stages and LO at VHF and above.
- Resolution bandwidth (RBW) is too wide to distinguish individual strong signals.
- In advanced instrument (2), a companion spotting receiver *(Analysierempfänger)* can be tuned to superimpose a marker over spike of interest on CRT screen.
- Selectable marker: intensified spike below x-axis graticule, or blanked spot.
- Spotting receiver has good sensitivity & selectivity, permitting more detailed signal analysis – spectral content & "fingerprinting" of signals.

Wellenanzeiger (spectrum analyzers)

Block diagrams *(source: Fritz Trenkle)*

1. Basic spectrum analyzer

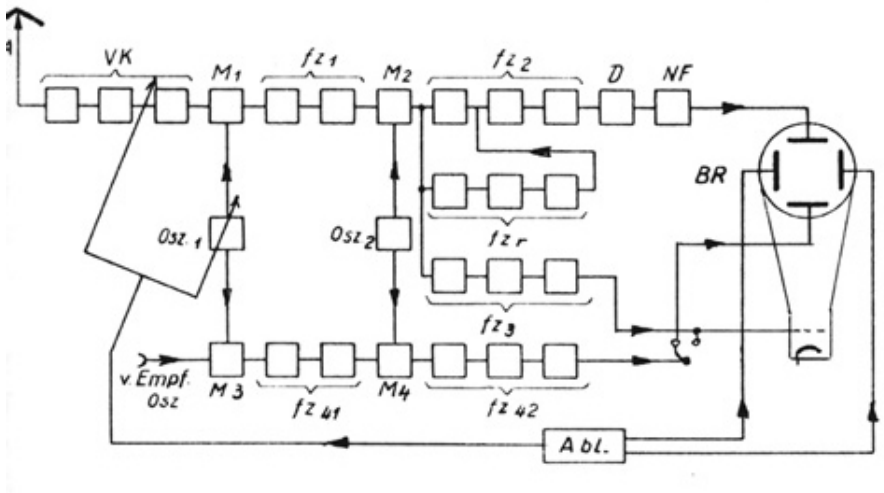
Horizontal deflection circuit (Abl) tunes preselector (V) and LO (Osz) via control windings.
IF (Zf) determines RBW.
IF block includes detector.



2. Advanced HF spectrum analyzer

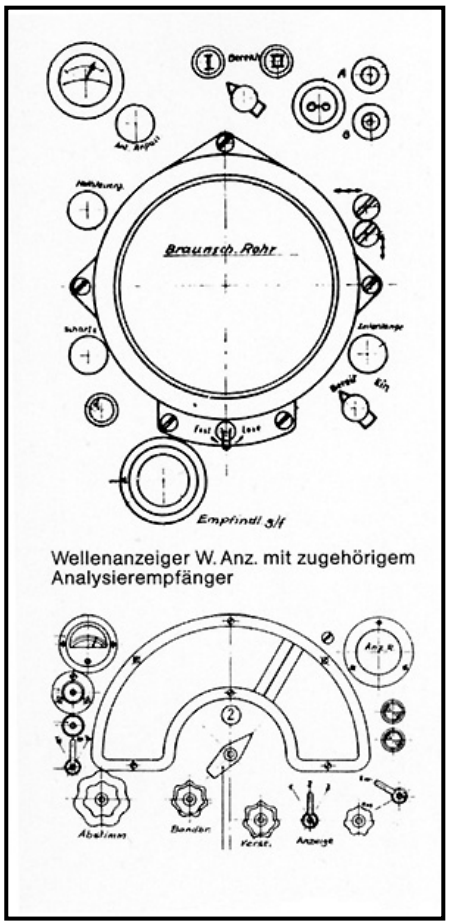
Marker IF chain provides tunable freq. marker synchronized to tuning dial of spotting RX. Marker signal fed to lower Y-deflection plate for spike, or to CRT grid for blanked spot.

D/F adapter w/loop, sense antennas allowed alternating display of signals from true and reciprocal bearings on upper and lower traces.



Wellenanzeiger (spectrum analyzers)

More images *(source: Fritz Trenkle)*



Wellenanzeiger W. Anz. mit zugehörigem Analysierempfänger

HF spectrum analyzer **W.Anz.** with associated spotting receiver.

VHF spectrum analyzer **W.Anz.g2** (FuMB 9) for 146-254 MHz. Push-pull RF amp and mixer with acorn tubes. RBW: ± 300 kHz. Sensitivity: 300 µV for 10 dB S/N.

Radar signal analysis:
pulse-width analyzers

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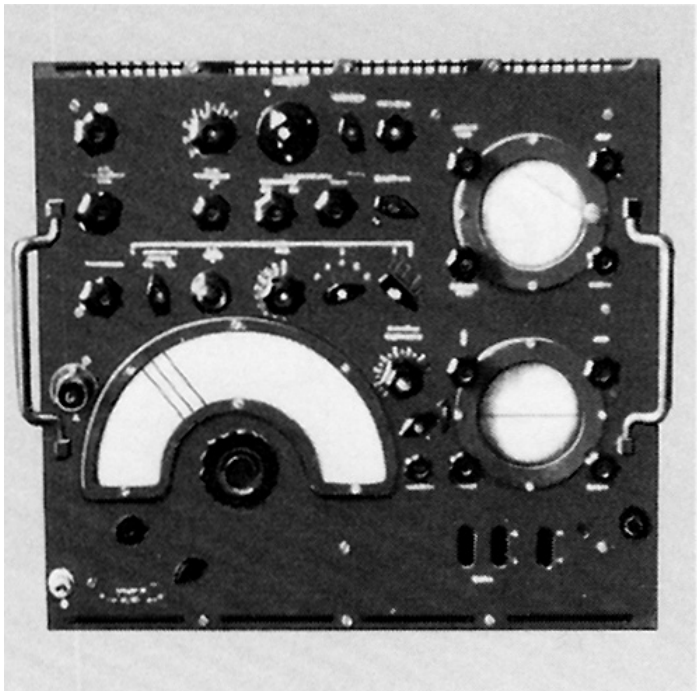
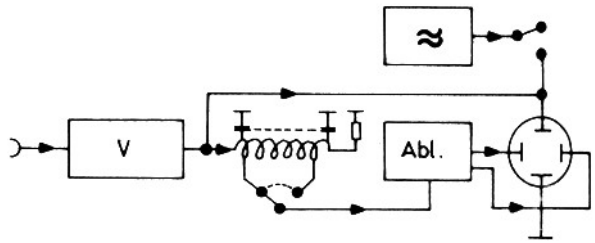
- Several W.Anz. models covering 75 MHz - 11 GHz were proposed, but most were built only in prototype quantities (if at all). At war's end, no deployed equipment covered critical RAF & USAAF R/T range (98 - 131 MHz).
- W.Anz.g series (146 - 254 MHz) deployed in large numbers, as it covered many Allied decimetric radars, including AI and ASV.
- Pulse-width analyzers *(Impulsbreitenmesser)* were also developed. These are specialized wideband receivers (B > 2 MHz), initially covering 19 - 72 MHz and fitted with an integral synchroscope.
- Designed to display and measure pulses (τ = 0.5…3 µS) with intervals in range 50…200τ. Results were vital to ECM/jammer development.
- Timebase is synced to pulse-train display on upper CRT. Delayed sweep uses flyback of main sweep to display intensified single pulse on lower CRT.
- τ measured accurately by comparing pulse to marker signals generated by calibrated internal HF oscillator, or via a tapped delay line.

Pulse-width analyzer

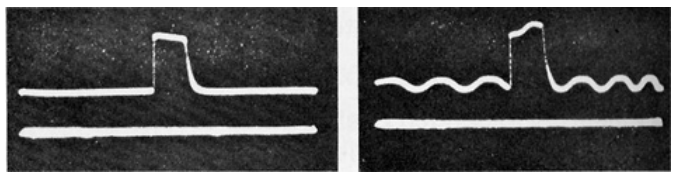
Images *(source: Fritz Trenkle)*



Hagenuk pulse-width analyzer Type 2



Simplified block diagram of delay-line analyzer



Display of single pulse without & with marker signal

Radio direction finding (D/F)
(Funkpeilen)

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- As this is a vast topic, we will consider only land-based D/F as used in detection of clandestine transmitter sites.
- A future presentation will cover naval, airborne and tactical land D/F.
- 3 types of clandestine radio sites:
  - Within Germany: *"Schwarzsender"* (often frustrated hams).
  - In occupied Europe:
    - Allied and Resistance agents communicating with SOE in Britain.
    - Clandestine broadcasters, usually Resistance.
- Agent transmissions: usually CW in 2 - 20 MHz range, from low-power (10 - 20W) "suitcase" or homebrew sets with stealth antennas, powered from mains or batteries.
- Broadcasters: AM, on medium and short wave with low-power homebrew sets or "liberated" military transmitters.

Radio direction finding (D/F)

Equipment: receivers, antennas, specialized D/F sets

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- Typical HF receivers: Fu.H.E.c, Fu. H.E.u (mobile or portable), E52 (fixed or mobile).
- Typical MF receivers: Fu.H.E.a/b (similar to Fu.H.E.c except for frequency range 75 - 875, 875 - 3750 kHz resp.)
- Typical D/F antenna: loop/sense, e.g. Fu.NP.E a/c D/F adapter.
- Large fixed D/F sites often used Adcock antenna array.
- Mobile D/F unit *(Funkpeilwagen)* had loop & sense antennas mounted on roof. Units disguised as commercial vans had antennas concealed inside wooden rear cab.
- Mobile units were fitted with abovementioned receivers, or other intercept/DF sets.
- Fu.H.E. AND Fu.NP.E series, being battery operated, were deployed as field D/F units.
- *Gürtelpeilgerät* (belt-worn D/F set) used on urban missions.

Radio direction finding (D/F)
Techniques

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- Fixed D/F stations initially triangulated clandestine transmitter site to within 2 - 3 km, then dispatched mobile D/F units via VHF R/T (30 - 55 MHz).
- Mobile units parked in area of interest and obtained closer "fix". As required, portable D/F units could be deployed on building roofs in general area.
- *Kofferpeiler* (briefcase D/F set) and *Gürtelpeiler* were developed for close-in "foxhunting" in urban areas. These sets were sensitive and inconspicuous. When he got close to the clandestine transmitter, the operator could hear its sideband noise by tuning off-frequency.
- In apartment buildings, officials observed pulsation of electricity-meter disc to identify precise transmitter location. This was preferable to switching off mains supply, as it did not alert clandestine operator. (SOE agents got around this by using battery sets, or by turning on the stove.)
- Clandestine ops tended to stay on the air too long, and D/F ops did not always maintain good radio silence (relying on clandestine ops' lack of VHF gear – but one wonders how many "foxes" were able to monitor the "hounds"…)

Radio direction finding (D/F)

Specialized D/F Sets *(source: Fritz Trenkle)*

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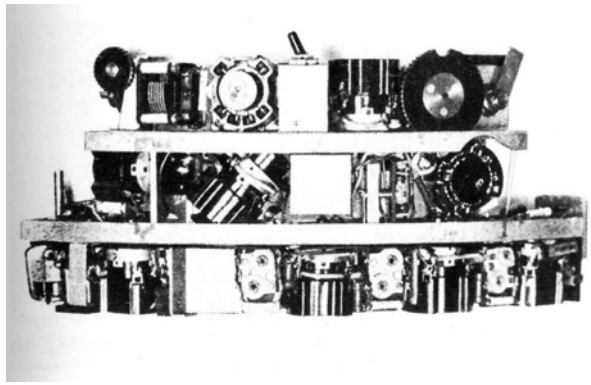
Gürtelpeiler worn on body. Concealable under clothing. Note neck-strap loop antenna & “wristwatch” S-meter.



Gürtelpeiler chassis. 7-tube superhet, 3 - 20 MHz, 2 µV sensitivity; 1 -3 km range with short wire antenna.

Kofferpeiler (briefcase D/F set). 7-tube superhet, 3 - 20 MHz, 2 µV. **Accessories:** single earphone, “wristwatch” S-meter

Radio direction finding (D/F)

Mobile D/F unit (Funkpeilwagen)

Images courtesy LA6NCA

Left: D/F antenna. **Right:** HF TX antenna.

Interior: Operator at EP2a RX (75 kHz - 3.3 MHz).

Future Presentations on German WW2 RF Topics

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- **Radio Direction Finding:** Allied & German land, airborne & naval D/F, including British "Huff-Duff"
- **ECM**: Comms and radar jamming, ECCM
- **Radar systems:** Ground, airborne and naval

Links for further study

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- Helge Fykse LA6NCA Website
  - *Sincere thanks to Helge for graciously allowing me to use his superb photos*
- LA8AK Radio Communications Resource Page
- Foundation for German Communications
- VA7OJ/AB4OJ Military Radio Page
  - Also see Military Radio Links