Some hardly known aspects of German military communications during World War Two

Synopsis

During the previous DEHS meeting held on 18 October last year at Shrivenham, it appeared to me - that everything that had happened outside Britain does barely exist, including a degree of animosity towards the US[1]. It has to be pointed, though, that the same may be said from the other side of the Ocean, where a similar lack of appreciation for what had happened abroad is also eminent. I truly believe, that historical distortions should be corrected.

My aim this time is to discuss aspects on - what was the philosophy behind German military communications and why have they commenced it this way?
Some aspects have been dealt with in previous papers, and will be omitted when appropriate. It is, nevertheless, unavoidable that some has to be referred to again.[2]

To state it frank and clearly, the aim (meaning) of this contribution is only to be considered from the perspective of fair historical interest and from the point of view of electronics engineering. The immoral implications of war, in particularly WW I and II, is always bearing in my mind!

Diemen, 11 October 2008

Subjects:

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[1] Whether we like it or not, without America's impetus Britain never would have gained victory. Whereas communists might have ruled, sooner or later, most of continental Europe, and Churchill knew it!

[2] Available on my website www.cdvandt.org please activate top button: 'Synopsis' on "The significance of German electronic engineering in the 1930s". Which paper was given at the international IEEE Conference on "100 Years of Electronics" at Bletchley Park in June 2004. Which latter is an enhanced version of my previous paper given at the IEE Conference on "100 Years of Radio" (Savoy Place, London, September 1995).

I. Introduction

The way in which Germany had developed their military communications goes back to the end of the 1920s. When their so-called "100,000 men Army" was still bound in the restrictions dictated (formulated) at the Treaty of Versailles in 1919[3]. The Germans were obliged to keep only very weak forces, mainly for internal security, where "tanks and air force" was prohibited (also their navy was kept very limited).
This was for many Germans not acceptable, and it was Walther Rathenau who arranged a secret pact with Russia in a side-letter to the Treaty of Rapallo in 1922.[4]
With Russia was agreed - that Germans could use secretly various training sites, far-off Western-European eyes[5]. Those who were engaged formally left military service, and were even removed from public records, without losing, however, their accumulated future rights (status) on pension and (military) promotion.

In those early days, very simple military tests (trials) were commenced with radios, mostly regular broadcast receivers, mounted in (very) light armoured vehicles (sometimes even made of cardboard). [1, p. 17-24] It is clear that these early trials were bringing very limited results, but should create some outline of new requirements. In the meantime industry was (also) developing new commercial communication systems on their own behalf, as the military services did not have explicit demands, maybe also owing to the financial depression worldwide.
From the early 1930s onwards, Germany's communication industry, as far as commercial (military) design was involved, could decouple themselves from the rest of the world, as they initiated entirely new set making technologies (please consider the reference given in footnote 2).
The C. Lorenz Company, since May 1930 fully part of IT&T, introduced for the first time, about 1931, a portable transceiver which was designed particularly for an expedition to the (tropical) Amazon region. This set has proved to be so successful that it set future standard for very stable (modular) apparatus design. The clue was, that the chassis frame was made of die-cast (mainly) Mg/Al alloy (called Elektron, in Germany also known as 'Spritzguß') (notice its composition @ Fn2 → Synopsis at pdf page 4). All modular sections were interconnected by means of connectors (male and female, omitting interconnecting wiring). This technology improved rapidly and after say 1936/37 it was custom that chassis and accompanied modules could be series produced in tolerances within 0.1 – 0.15 mm.

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[3] Professional force, no conscripts. Known as "Reichswehr".
[4] Dr. Rathenau, who was Jewish, was Germany's minister of foreign affairs. He was killed the same year by a fanatic nationalist, because he was blamed (in revenge) for the devastating outcome of the treaty settlements (dictated) at Versailles in 1919.
[5] Army (tank-like vehicles) and (regular) aircraft could widely being used, be it, that these sites were headed by Russian Commanders. The Germans possessed during these years no air force ministry nor military aircraft. After Hitler came to power, the German Luftwaffe was (secretly) established October 1933. During the same month Hitler closed the agreements (settlements) with Russia (USSR).

The second important improvement was the introduction by Hescho of a wide range of temperature controlled ceramic capacitors and trimmers[6]. By this means it became possible to control (neutralize) the influence of temperature versus frequency response (deviation). A spin-off from Hescho's work[7] was the introduction of ceramic solenoids (coils or inductors) with deposited silver kept in spiral (helical) groves. This latter technology increased stability enormously[8] and to some extent its Q-factor.
Thirdly - slightly earlier Hans Vogt came up with the combined application of carbonyl iron powder[9] bound in low loss material. Iron powder was known already in conjunction with low frequency applications, though, it was since him that, particularly in Germany, dust cores became common standard in set making designs (even in regular broadcast receivers)[10]. Dust cores were even very successfully deployed by Lorenz in low and medium power transmitters, overcoming saturation phenomena. (Regard Fn 2 for additional information)
After the political changes of 1933/34, official demands for so-called special (standard) valve designs (Behörden-Röhren) occurred, and industry was encouraged to cooperate, resulting in a range of standardized valves, first series for battery and thereafter for 12 volt applications[11].
In all other countries, radio valves were similar in broadcast sets and for utilizing in military applications[12]. In Germany, however, these valves should, including their base-holder, be integrated in the set design entirely, which allowed fully three dimensional set making[13].

Photo 1

From left to right: RV12P2000 within its socket and without; RV12P4000 with and without and type RV2P800. The P4000 and P800 valve envelopes were (shock) buffered by means of rubber rings inside the Al shielding tubes (cylinder). The RV2P800 had blue markings on top of their puller-grips. The RV12P4000 was marked green. The RV12P200 used a modified white marker, visible at their valve base. This allowed layman to recognise what valve type is involved. This was important, as from outside one could not always see type-numbers. Inside these valve pullers were small equalizing capacitors, which compensated Ca to some extent. By this means, valves, even at VHF, could be interchanged without too much frequency deviations. The (prefix) number following 'P' is a measure for their static amplification factor.

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[6] DE721707 application date 2 February 1934 (Kahla). See also 'Hescho product guide of 1939' (Fn 2)
[7] Hescho was owned by the Kalha company, who produced all sorts of ceramic devices. After, say, 1934/35 these products were widely available on the German market.
[8] Stability improves about 200:1, compared to wire-wound versions.
[9] Unlike Fe powder, carbonyl iron differs in nature, as it is spherical (1 – 2 μ) and has no sharp edges and consequently lowered (minimized) RF Eddy currents remarkably.
[10] Ferrocard, was also available in Britain.
[11] RV2P800, RL2P3, RL2T2, RV12P4000 and RV12P2000, RL12P10, RL12P35 (please regard reference in Fn2)
[12] In Britain, they introduced special Army valves, though, their appearance was like regular (civil) design.
[13] Please consider: 'Die Einheitröhre', available on my website (Fn 2).

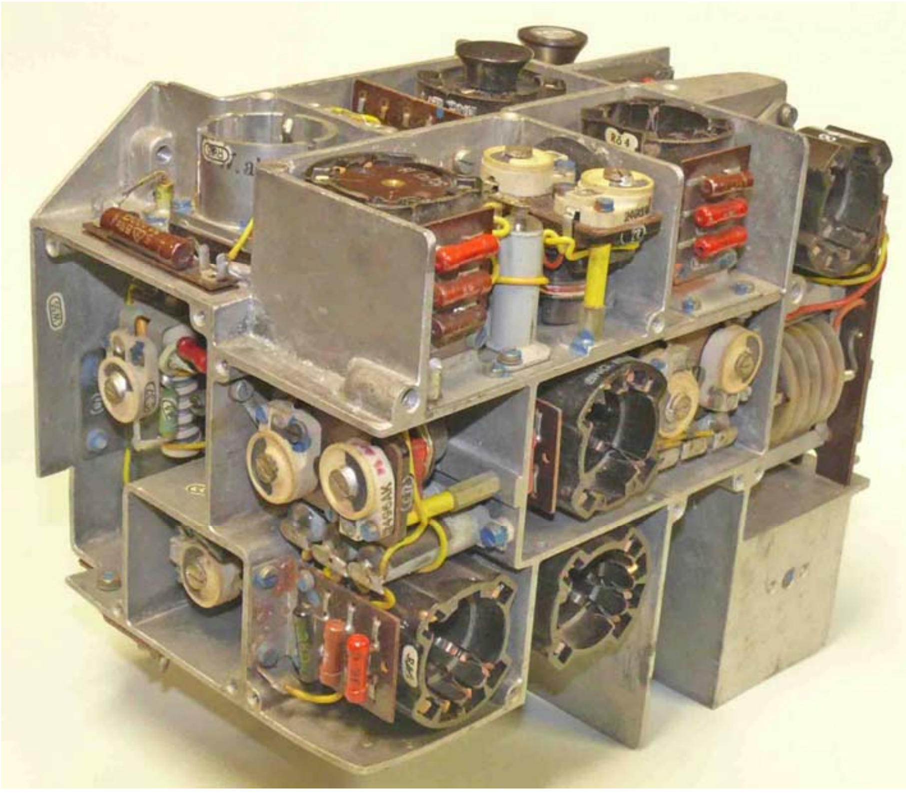

Photo 1a
Shown is the RF module (transmitter and receiver) of FuG 25a (IFF transponder). This is a nice example of modular construction. The die-cast frame is also acting as RF screening. These modules were fully covered by Al plates, sometimes even by means of die-cast plates.

II. Pre-war Army and Air Force (GAF) demands

An important spin-off of these new technologies was, that it became possible to ignore quartz crystals as frequency determining element (device). All industrial countries had to import raw quartz, mainly, from Brazil. And, everything that had to be obtained from abroad would use (demanding) foreign currency[14]. In wartimes it is evident that supplies easily can be interrupted. This was true for most foreign products like, for instance, rubber or simply crude oil[15]. Autarky, was taken very seriously by the Third Reich – whether they had, straight from the early beginning, a future war in their minds remains an open question. Though, has to be regard positively for the time after the re-occupation of the "Rhine-land" in 1935. A major role was played by the "Vierjahresplan" institutions, headed by Göring (four years planning). To some extent, it may also be considered creating (providing) promising export products. In

[14] Most transactions were maintained via a so-called "Clearing Office". Which often means, a State to State exchange transaction. A product was exchanged against another product purchased in their own country. This was common practice, worldwide. During the war, Switzerland delivered, for instance, special roll- and ball-bearings to Germany and in return they received coal. Similar happened with Sweden. Resulting in a more or less neutral payment balance, where hardly foreign currency was involved.
[15] IG Farben invented Buna, a full substitute for natural rubber. The Fischer-Tropsch process allowed their "Hydrierwerke" to convert coal into petrol and lubricants too (like: diesel, naphtha and high grade aircraft fuels and derivates). Both technologies proved to be of strategic importance!

the 1920s and 1930s, IG Farbenindustrie had strong commercial interests (tights) within the US; however, the reverse was also true[16].

Two main examples are given: FuG10 (long distance short wave) aircraft system, and VHF sets deployed in tank communications. Of which latter the most common ones were UKWEe and 10 WSc. This receiver and transmitter operated in the range of 27.2 – 33.3 MHz divided in 50 kHz channels. It was used throughout the entire war and more than 150,000 sets were procured. Very minor changes were commenced, mainly to simplify design and saving scare materials.

Albeit, some would say, stop - we also made wireless sets running without quartz crystals! But I doubt, that it was common industrial practice to design sets about 1938 (actually designed 1936/37), which operated under military conditions (like for tank radios) in the VHF ranges effectively (anticipating the enormous shock and vibration levels). [1]

The frequently heard complains - that German design did not allow modifications is, in my view, not valid; as owing to its modular structure individual changes seemed still possible. But, what count is, that straight from the beginning design should be right and being state of the art. Telefunken, in those days, certainly could manage that[17]. (please consider for details on FuG10 Fn 2, 'Synopsis') Also Lorenz was a very sophisticated set designer, and FuG10 underwent later some design changes, but the interconnecting wiring was such that modules could be changed (re-designed), so that their interface requirements were kept the same. When straight from drawing-board, systems are being designed with clear vision of specifications, changes can most often be dealt (anticipated) with.
Lorenz made also standard VHF sets for Ground to Aircraft (Aircraft to Aircraft) communications for up to say 60 MHz, some even for shorter wavelengths, without using quartz crystals at all. With the exception for using a single one in a separate (service) calibrator for each installation (station).

Going back now to the late 1920s and early 1930s, standard army requirements were: long and medium waves, which provided skip free ranges for up to say 150 km. Very popular was the Lorenz set LS100/108 also known as 100 WS, which covers 200 kHz – 1200 kHz. Some tactical communications were commenced in this range. However, most favoured was what the Germans called "Grenzwelle", covering 1000 – 3000 kHz. When we ignore the mix-up of various types originating from the early 1930s, in 1939/40 the 30 WSa and after 1941 the 80 WS became the standard army transmitter sets between regiment, division and/or Army HQ.
The finest "Grenzwelle" receiver, having equal (mounting) size as UKWEe and/or 10 WSc, is Telefunken type MWEc[18] [19]

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[16] Opel – General Motors US; Ford – Ford US; C. Lorenz - IT&T (Standard Electric); AEG had strong links to GE in the US; Osram owned by both AEG and Siemens & Halske, had also links to GE. There existed also an international light bulb cartel 'Phoebus' incorporating Britain, as well.

[17] It might seem that design originate from a particular company, but what ultimately was created was always the result of close cooperation with military ordnance like - Wa.Prüf 7 for the Army, Gl/LC4 for GAF and NVK for the Navy.

[18] MWE = **M**ittel**w**ellen**e**mpfänger type c (medium wave receiver) range 980 – 3000 kHz in two bands, incorporating a double tuneable quartz filter. I believe, one of the best receivers of its kind in the world! Extremely compact, using 9 x RV12P2000 valves. The prefix figures 30 and 80 to 'WS' tells us that their output power is 30 or 80 watt. (…WS = …**W**att-**S**ender)

[19] The combination UKWEe + 10 WSc was called Fu5; 80 WS + MWEc was known as Fu12 (Fu8)

We neglect, for this occasion, the deployment of the 1/1.5 kW long and short wave long-distance mobile transmitters.

The German army deployed, nevertheless, also relatively short distance (portable) VHF communication systems. Since 1935/36 the well engineered Torn.Fu.d2 (33.8 – 38 MHz), which brought in speech mode (A3) ≈ 4 km and in A1 (CW) it covered proximally 10 km. About 1941 they introduced the relatively small portable Feldfu. b and c. (90 – 110 MHz respectively 130 – 160 MHz) and Feldfu. f sets for the "Panzergrenadiere"(tank infantry) which frequency range operated, logically, on the same band as for tank to tank communications (27.2 – 33.3 MHz). These handsome sets (all having the same housing types) were carried on their back, for a remote control was fixed onto their belt, as to control loudness and receiver fine tuning. These sets were also designed to be operated stationary (Bodenständigesgerät). Their operational range was proximally 1 – 2 km (when sight in between was clear a much longer range). In the second half of 1944 they introduced (crash program series up to 15,000 devices) a quite small and compact portable set (32 – 38 MHz), which was carried on the soldiers breast, and was called "**D**orette" (Kl.Fu.spr. **d**). The channel numbers equalled those of Torn.Fu. d2. Dorette could be operated with a set of batteries for about 24 hours.
Occasionally, the post war Czech remake (with miniature valves) can be found at UK rallies.

We may estimate that from, say, early 1944 onwards, Allied troops were far more equipped with radios of all kinds than was the German army. They increasingly lacked resources to replace lost communication gear (particularly following the Normandy disaster). Relieve brought, to some extent, the deployment of the Dorette. They were, nevertheless, skilled to manage (cope) with what they had at hand. In this respect heavily relying on telephone systems, as well.

In Russia the Long/Medium and "Grenzwelle" proved to be very important, as distance had to be count sometimes for in hundreds of kilometres[20]. Short waves were not deployable, as their skip zones are changing all the time (more or less unpredictable). They deployed, however, also fairly low power sets (2 - 15 watt) running in the frequency band of 3 MHz to ≈ 7 MHz[21], but these were used mainly for relatively short distance communications, like artillery observations, albeit, some for up to (their) full ground-wave propagation or even beyond.
This might have influenced Allied interception of German communications from that area, as long as short wave links were not involved in the chain of command. In Western-Europe the Germans were very keen to use fixed telephone lines, be it rented from local PTT in the occupied countries and/or their (own) Reichspost and/or deploying their widespread European military telephone networks (both, army and luftwaffe deployed their own networks). For long distance calls their signal route passed often through various organisations (exchange systems). It was even possible, to make, for example, European wide phone calls interconnected (switched) in 'conference mode' between: the Leningrad front – Germany - Crete and Bordeaux[22].

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[20] I always wonder, whether then already Cyprus was a main British interception base, and did they possess a regular telegraph cable to Britain? If this was the case, then it would enfold how BP could get their Colossus intercepts (Lorenz SZ40/42) from that area (for instance, Greece). These were normally transmitted by means of rhombic antennae, which are highly directive and were not facing (pointing) towards the UK.
[21] Torn.Fu.b / f / k, Torn.Fu.g, 15 WSEa/b … .
[22] Regard my CHiDE paper of 1999 on "Some aspects of military communications as deployed by the German forces, prior to 1945". Bournemouth Autumn Symposium. See also Fn 2 for my website URL ('Line communications').

Albeit, the bulk of strategic communications were handled by means of telex (Fernschreiber = teletype) and utilized telephone lines extensively[23].
Wireless communications were, nevertheless, maintained, but primarily for training purposes. Only in areas where telephone lines were rare or not existing, there remained the full deployment of wireless. My late friend Stanley Cook (G5XB) told me once, that the bulk of German intercepts was appearing after situation was becoming chaotic[24]. When telephone lines were becoming un-secure and overloaded (disrupted). This was happening in Italy after the Allied landings in Sicily August 1943 and after D-Day (June 1944) in France. Maybe sometimes earlier, as disruption often started prematurely, aiming to disable German reinforcements.

Photo 2
MWEc, high performance receiver

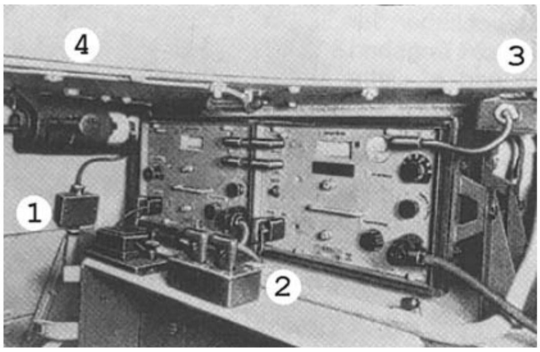

Photo 2a
UKWEe and 10 WSc inside a light tank

III. Interception service

The German interception service started after say 1933 using commercial receivers which design went back to late 1920s and early 1930s. As we have already noticed, components, chassis and valves, thus, entire set designs progressed rapidly, and it was clear that interception services required the supply of new, state of the art, apparatus too. To keep my summary within limits, the result was, that starting with 1939, a wide range of so-called "**Fu**nk**h**orch**e**mpfänger" or interception receivers were purchased (some sets were introduced in 1941/42). Their nomenclature was FuHEa – FuHEb – FuHEc …f (covering 75 kHz – 305 MHz), the frequency range being the main difference. [2] What they all have in common is, they use battery valves. This might also originate from late 1920s or early 1930 (radio) requirements, where mobile (army) deployment was thought to be relying on 2 V Pb or later 2.4 volt NiCd batteries[25] (liquid, non-spillable accumulator types). The Luftwaffe was first to focus for all valves on 12 volt applications. In aircraft where 24 volt was standard, two valves had to be wired in series. One very important decision was that, where ever possible, the number of valve types should be limited. This had a huge impact on spare parts(ordnance). Most receivers used throughout its circuitry only a singe valve type like: RV2P800,

[23] Only for special long distance telex links the Germans deployed wireless (Sägefisch or Shark as British called it). The Colossus at BP was built particularly to break into the Lorenz SZ40/42 system. Though, was not constructed to crack the Siemens SFM T52 d /e machine codes (British code-name: surgeon), which appeared too rarely on wireless (mainly relying on telephone lines)! Which would have been far more difficult as its security was of a far higher level (standard) than was Lorenz type SZ40/42!
[24] He worked for many years at the BBC monitoring station near Reading. During the war he was particularly engaged in the interception of German Hell-Schreiber traffic. (regard ref. in Fn 2, topic 'Rudolf Hell')
[25] When appropriate, the HT was derived from the 2 or 2.4 volt (filament) battery, by means of a vibrator pack.

RV2.4P700, RV12P4000 or RV12P2000. Transmitters used, mostly, RL12P35 (GAF later LS50).

Photo 3

Interception receiver: Funkhorchempfänger c (Fu.HE.c). Consider the blue marked text below. The coloured scale is calibrated in kHz, until about 1942 all scales carried on their back-side a scale calibrated in λ (wavelengths). Which might originate from early 1930s requirements.

After the war in 1947, Mr Farrar published an interesting article in which he explained very intriguing design details, of which I must admit, one never had come up in my mind before. [3, pp.63-66]

The outstanding feature of German army wireless sets was the almost universal use of lightweight alloy of their construction. … Instead of using a single chassis with components mounted above and below, the Germans mainly used a system of unit construction. The various stages or sections of an equipment were assembled separately and these sub-units bolted on to the main cast framework. Final inter-unit wiring connections were made by solder tags, lugs and screws, or plugs and sockets. Thus in the case of serious electrical or mechanical defects arising, a whole unit could be replaced and the equipment put back into service with a minimum of delay. While this method of construction simplified maintenance and gave additional mechanical rigidity. The 10-watt tank transmitter (10 WSc, AOB) *was for all practical purposes the same in 1945 as in 1937. Ceramics were used extensively in various ways: moulded plates for mounting components, tubes, as coil formers and rods as control spindles, particularly for variable tuning condensers …Components were all of good quality…*The following was new to me, AOB .. *Another form of simplification was found in*

the range of intercept receivers. Here the tuning control (coaxial fast and slow-motion) was positioned to the left of the centre-line of the (front of photo 3, AOB) *panel; near the bottom, and adjacent to it on the centre-line were edgewise controls for bandwidth and volume, and an A.F. tone filter switch. The operator, using his left hand could, while listening to a signal, vary the tuning with his fingers, and the bandwidth, volume and tone-filter with his thumb, thus leaving his right hand free to take the signal on paper.* …(next was already known, AOB) *Sensitivity of all superhet receivers, even those dating from 1936, was good … and compared well with similar British equipments …A 1945 model of the receiver for tanks* (UKWEe, AOB)*(the design dating back to 1937) had so little background noise that, when it was switched on during tests, it was thought to be out of order. Selectivity was adequate, and in case of most low and medium frequency superhets and in all intercept receivers, bandwidth was adjustable either continuously or, in some steps; a crystal filter was fitted in some instances. …The stability of sender and receiver oscillators, combined with crystal calibration and the large-sized scales, made netting procedure very simple.* His finally conclusion: *The points of German army wireless equipment can be briefly summarised as follows. From the mechanical viewpoint, German equipment was very well built, due to rigid light-alloys castings, anti-backlash gearing and accurate construction methods; Electrically, the equipment was good and efficient, but not modern when judged by British war-time standards, although, it was in some cases quite ingenious.*
So far Farrar's explications, we continue now with our survey.

Rommel relied during his North-Africa campaigns very heavily on the skills (quality) of his interception services, as this was his best source of information! The defeat (surrender) of Tobruk was mainly owing to systematically intercepting British communications. During the first battle of EL Alamein, Rommel's main interception section was captured after a severe fight, with the loss of 100 of his men (most dead). This latter figure shows us that this interception unit must have been rather big. What the British troops discovered was striking. It was found, that British communications were nearly all intercepted and more significantly – understood (breaking into British Army, Navy, and Air Force codes)! This severe blow resulted in a complete change in the way British communication was maintained since. Thereafter, the Germans were unable intercepting fully (understanding all contents of) British communications. What they, nevertheless, still did (could) was, they monitored systematically various communications, which still allowed them to draw conclusions, though, never as fruitful as before October/November 1942! [4, p.65-74]
However, to close this paragraph, Wilhelm F. Flicke pointed:… *In its several parts the interception service was very well set up and achieved useful results in numerous cases. … Which was definitely defective was the use of the results of this service. National Socialism was a system which sabotaged itself in every way and on the long run achieved opposite of what it sought*[26].[5, p.213]

IV. Tank communications

Both photos below are more or less well known, and probably one of the most reproduced of its kind. Shown is General Guderian during the 1940 campaign in Northern-France. He is standing in a half-track vehicle (German name SPW). Comparing the first with the second

[26] Consequently, the effectiveness of German intercept services depended heavily upon the service (division) to which they were affiliated. For Rommel counted only the results and, Nazism was not his peace of cake.

photo, we see that photo 4 (published in a book of 1940/42) the censor had ordered the cut-off of the enigma machine[27].

Photo 4 Photo 4a

General Guderian standing in his commands SPW during the campaign in Northern-France 1940. Photo 4a is curious, the plug-board section of enigma has been covered by means of a white strip. (Photos taken by PK-photographer Borchert)

Photo 4a had been reproduced many times, though, what, to my knowledge, nowhere has been noticed before is, that the "Stecker" section (plug board) had been made invisible. What they did was, covering it by means of a white field. The wartime censor might have been aware of its delicacy[28]. It is, though, most likely that photo 5 came only to daylight after the war. Curious is, that this photo is reproduced in conjunction with various photo sources (de,uk,us). I have discovered, however, who really took them: it was PK- photographer Mr. Borchert. Appropriately, he should (also) be credited.

However, the main difference between the wartime and the, say, 1928 commercial Enigma machine is, that these early devices were not equipped with plug boards (Stecker) provisions.

It was the German Navy who first showed interest in Enigma and they initiated the implementation of the plug boards, as to enhance system safety[29].

[27] The army (Heer) and GAF (Luftwaffe) both called it Enigma, whereas the Kriegsmarine called it Schlüssel M

[28] Or, had they prematurely put themselves a white cardboard strip on top of the plug board section? As many visitors were actually around during these (sensational) operations (of whom not possessing security clearance).

[29] Please regard on my website, the contribution on collected 'Enigma patents' and related matters. (See Fn 2). One cannot trace any Enigma patents applied for after about 1930. A few had been granted in the early 1930s, but their application date originate always from before, say, 1930. I believe, that since German military services were starting to adopt enigma, civil (commercial) business stopped (ceased). An important factor may have been that commercial 'Enigma' never gained sufficient profits.

Photo 5

Commercial Enigma type D. It was sold in 1928 to a, probably Dutch, banking institution. This special version had a step counter and a crank (clamped onto the bottom of the cover-lid) to allow rotor (wheel) steps back or forward. Visually, it equals the machine shown at photo 4a, but it clearly has no plug-board provisions. (Photo by courtesy of Paul Reuvers)

However, one would easily get the impression that enigma was used in tanks as well, as Guderian was the founding father of the German armoured forces, particularly tanks. This was not the case[30]. For tank and related communications they used so-called "Doppelkasten-schlüssel" and after late 1944 "Rasterschlüssel", which was more easy to handle during operations (rather simple kinds of cross-tables), as these should be handled during operations when moving. Consider – sitting in a dark tank compartment – moving (shaking) - writing down a message on your thigh - having only light of a dim light bulb). [1, p.119]
Tank communications were mostly maintained (handled) in normal speech mode (A3)[31], as the significance of information exchange was only tactically lasting for a quite short period. Nevertheless, still using code-words for special purposes and/or instructions (A2 - tone modulated CW was also possible, but not very popular). The VHF range of UKWEe/10 WSc was on the move about 1 - 3 km (depending on the local terrain), when used stationary about 4 km (deploying a 2 metre antenna rod). Sometimes, these signals originating from tank to tank communications were heard in Germany by licensed radio amateurs. In contrast to what one may expect, Germany allowed up to 120 (some say more) radio hams to operate also in the 10 metre band throughout, say - May 1940 to May 1945! (see Fn 2 'DASD-CQ 1937' and click then for a UK contribution at: DASD-CQ 1939-44 → find a half way down that page 'Bitte QRX, Krieg' by Michael Ockden G3MHF)

Guderian is standing in his command SPW, what can we deduce from it? Down in the background we see a metal frame, which could carry (holding) a VHF (Fu5) or a medium wave communication set (Fu12 or Fu8). I would guess his SPW was equipped with both, VHF and medium wave systems. As his command post (station) should listen into (maybe

[30] When there is a likely chance that accidently sensitive coding machines could fall in enemy (foreign) hands, their application was prohibited.
[31] Using throat-microphones and special acoustically insulated headphones.

taking part in) VHF tank communications, as well as keeping in touch with higher staff be it - division, brigade or headquarters level[32]. Which might often cover rather long distances up to sometimes 300 km. German tank formations in 1940 - 42, operated often fully independently. They were sometimes hundreds of kilometres ahead other formations like infantry. Relying fully on their own support and supply services[33]. Major General Erwin Rommel's fame originated from his campaign in France 1940, where he headed such a fast advancing tank division successfully (7th panzer division). He later became well known in Britain as he headed the Afrika Korps (after Tobruk becoming Field Marshal).
However, for longer distance they used 30 WSa transmitters in conjunction with either Torn Eb or MWEc. On this (high) communication level, the standard procedure was accomplished in CW (Morse-code = A1), and (wireless) communication (information exchange) was always handled by means of enigma.

Later in the war, these kinds of mobile command stations were often also equipped with fully featured VHF ground to air equipments. As coordination between army and air force was often of tactical (crucial) significance.

V. Special navy requirements

The German Navy was, like in most other countries, rather conservatively orientated. They did not adapt new technologies easily, and it took sometimes a decade before new systems were finally accepted. Their main supplier was Lorenz and the navy hardly used Telefunken systems, with one main exception and that was where U-boat was involved. Although, even for this sensitive occasion, they still adopted, habitually, rather conservative apparatus, which design often originate from the early 1930s. For instance, type VII U-boat was mainly equipped with receivers type E437[34]. Certainly not a state of the art set, I presume it did its job as expected. However, their U-boat short wave transmitters were, in contrast, very well designed!

The Kriegsmarine (Navy) was originally very opposed to the deployment of super-heterodyne receivers. Understandable from the perspective of early 1930 technology[35]. It is true, that onboard navy ships, cross-modulation and false signals can be generated owing to very strong signals originating from various transmitters sometimes only a few metres apart. TRF (straight forward receivers) was a good solution. This is why the German Navy purchased their standard receiver type Lo6K39 made by Lorenz; a high performance set which was often deployed at naval interception sites too. It has to be said, though, that after, say, 1941/42 they also purchased Telefunken T9K39 receivers (codename Main), which had three RF amplifier pre-selection stages, all band-filter coupled and tuned by means of a 7 section tuning capacitor! (neglecting for new boats the 'Köln E52b2' from 1944 onwards)

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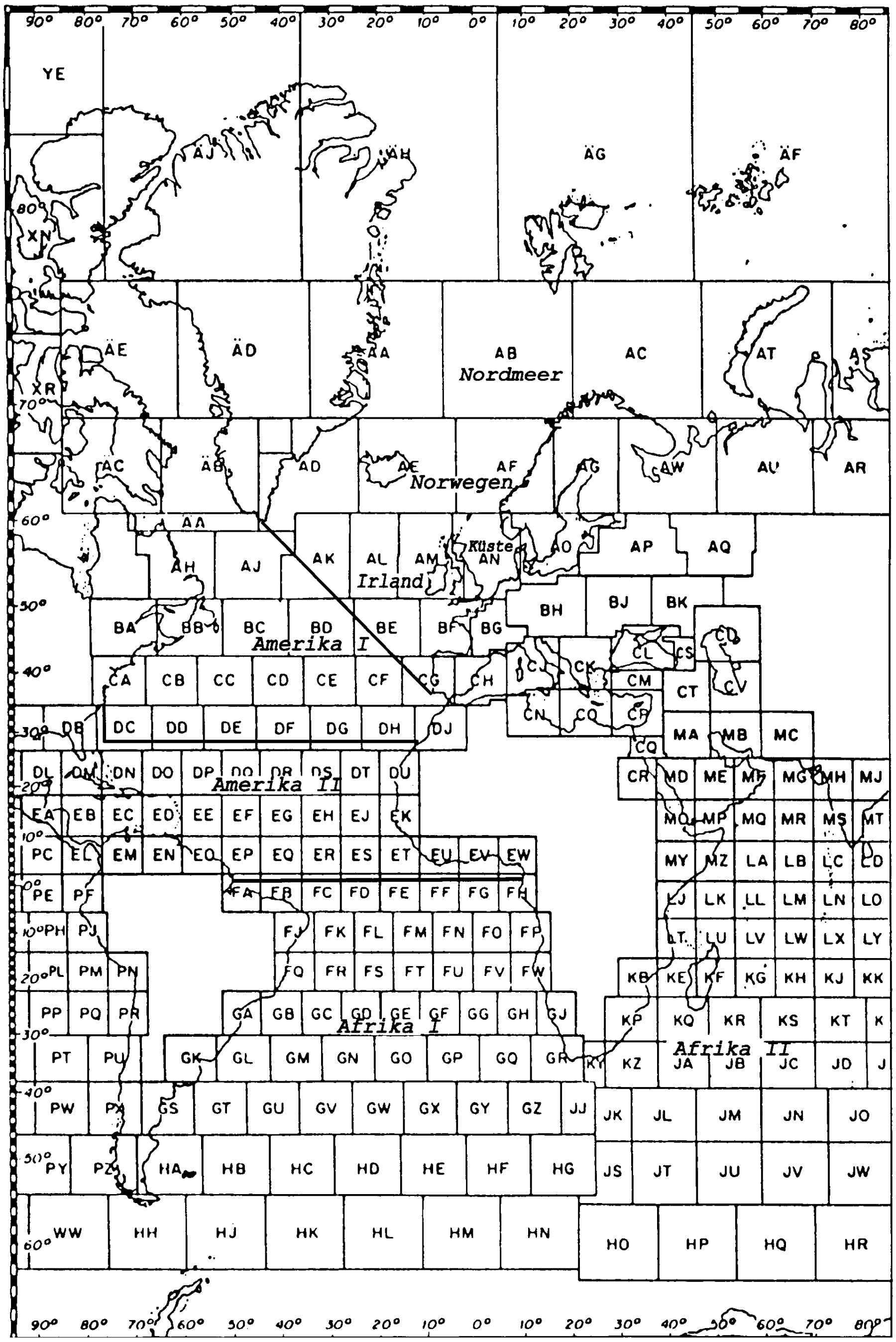
[32] There existed also real battle-command-tanks, equipped with Fu5 and Fu12 (Fu8) and other systems. Although, I doubt that they had enigma onboard.
[33] A standard German division counted about 20,000 men. Only 2000 - 4000 men were actually fighting, the rest had to provide service and support. Such as: repair of gear, ordnance, food supply and so forth.
[34] U-889 (type IXC/40) surrendered in May 1945 to the Canadians at Nova Scotia, was still equipped with this, in my view, obsolete receiver type, regard [4, p.55 at fn 2]. We have, though, to take into account that coastal (shore) stations used often high power transmitters of sometimes 10 kW. So that signal levels could often be sufficiently high. Fritz Deters told me once, that when he saw this RX in his U-boat, he was very disappointed!
[35] Maybe, also fearing the danger of unwanted (interfering) radiation of first-local-oscillator signals.

Let us take a closer look in the organisation of U-boat communications.



U-boat map of western hemisphere.
So-called ‘Planquadrat-Karte’. In enigma traffic, these figures represented the actual map locations.

When the war started in 1939, there barely existed a fearful U-boat force. The real building-up started after the consolidation in Western-Europe July 1940. Ignoring some previous U-boat operations. Particularly in France and Norway, they started building gigantic heavily armoured U-boat-bunkers[36] [6, 6a]. And, new boats were entering service from early 1941 onwards. Many boats were still rather small (type VII), and not really up for Atlantic

[36] Armoured concrete roofs between 3.5 – 7 metres!

operations. They could not stay tactically at sea long enough, and the number of torpedoes was also limiting their offensive power. Particularly when they should operate in theatres like the American coast or in Caribbean waters.
It is clear, that under these premises, the U-boats should be kept under a strict (tight) control. Which 'high command' was known as B.d.U. (= **B**efehlshaber **d**er **U**-Boote) and Dönitz its commander, throughout the war. Lorient (Kernével) their main HQ in France (Dönitz later moved, for safety reasons, to Paris – and finally Berlin). Lorient, St. Nazaire, La Pallice (La Rochelle) and Brest were their most important U-boat ports. [6a] [7] [8]

Tactically and strategically was it significant to control (leading) U-boats in groups, sometimes known as "Wolfpacks" (Rudeltaktik) although, the Wolfpacks designation is historically not entirely correct. However, U-boats could operate in groups far more effectively against ships and convoys then when they operated solely.
It is therefore quite understandable, that B.d.U. kept close contact to all boats, as to know what the actual situation is. But, also keeping an eye on the state of their fuel storage left and, eventually, the numbers of torpedoes. When, for what ever reason, a boat had to return to his home base, he, could or should, hand over fuel or torpedoes to fellow boats so that they could stay tactically longer at sea. It is evident, this could only be accomplished as long as they had a good image on what was actually the state of affairs[37].
It is clear that this oversight forced, inevitably, the extensive deployment of wireless communications. With the danger of being intercepted, or even facing the danger of breaking into their own coding systems. They knew that this might be the prize to be paid for this kind of strategy, relying thus heavily on the (lasting) security of enigma. [9]
In some publications, the impression is given that the Germans did not care much about security aspects. But this is nonsense! M.Dv. 922 is a "Dienstvorschrift" (instruction manual) which extensively deals with nearly all aspects of naval communications; they every time expressed that under all circumstances message safety should be kept utmost tight. Also, the so often mentioned break-throughs in Bletchley Park's huts were, eventually, foreseen!

Let us, for instance, follow now what happened(appeared) when a U-boat left their German base like Wilhelmshaven and went sailing to the coastal waters of Brazil. This map is copied from my book on U-boat communications versus Huff-Duff. [7, p. 158] I have not changed the German designations, as it is quite clear that Amerika means America – Ierland = Ireland and Küste means coast.

The first wireless "Schaltung" or area control was "Küste"(coastal waters)[38]. Which covered more or less the North-Sea area. As it was impossible to cross the Pas de Dover and the Channel, the only route was passing through the gap between the Penn-Isles and Farör Islands or north of it. Entering the so-called 'Ierland Schaltung'. A different organisation section took over the control of boats in this area. After crossing a certain longitude, the boat was handed over to Schaltung Amerika I and thereafter to Amerika II (eventually Afrika I). The area, though, obliged what naval code was valid, as each area had their own machine settings (for

[37] Later real U-boat tankers were deployed (type XIV). These rather big U-boats (nickname Milchkuh = milk cow) carried quite some diesel fuel, though, also spare parts and they had a (real) doctor on board. On their return trip they often also brought back home (captured) captives. When a sailor was ill, he also could be repatriated by this means. Owing to Bletchley Park these boats was hunted especially for. So that in the course of 1943 hardly one had survived. It has to be said, though, that U-boats taking over supplies, were being forced to be linked together with the supplying boat for quite some time, sometimes, even two boats were refuelled at once. And, logically being an easy target for aircraft constantly patrolling ocean waters (thus highly dangerous (lethal) with or without Ultra).
[38] Regarding mostly the application of frequencies, appropriately for relatively short distance communications.

wheels and plug board). It has to be explained, though, that the communication (shore) stations could not see whom was sending and from what area (Schaltung) a message was received. Coastal stations were (mainly) a communication channel, not more then that!

Although, from our today's knowledge not so wise (smart), B.d.U. wanted to know on nearly daily base weather reports (WW message). These were very significant to them, as by this means it was only possible to predict (forecast) European continental weather[39]. Also, have they eventually seen any kinds of ship movements, what was the state of fuel, torpedoes and so forth?
Reporting ship movements was tactically (and, strategically) important, as this allowed B.d.U. to organize coordinated action against single ships or convoys. When a target was acknowledged, it was then to decide where the U-boats should become engaged in an attack. Boats had often to sail for up to thousand (eventually more) nautical miles, before reaching the area of combat. All parameters should be kept on record, who was where and what where their supplies and so on.

It is clear, that there was for them no way around the application of wireless communications!

How where their shore stations organised?

Tabelle B: *Das Leitfunknetz des B.d.U., 1942/43*

Funkstelle	Leit-welle	Irland		Amerika I			Amerika II			Afrika I		Afrika II		Küste	
		KW	LäW	KWa	KWb	LäW	KWc	KWd	LäW	KW1	LäW	KW2	LäW	KW	LäW
M.N.O. B.d.U.	LSt	LSt	S	E	E	E	E	E	E	E	E	E/S	E	E/S	E
M.N.O. Bernau	GSt	E	E	LSt	E	E	LSt	E	E	E	E	E	E	E	
M.F.S. Villecresnes	GSt	E		E	LSt	S	E	LSt	S	LSt	S	LSt	S		
F.d.U. West	GSt	E/S	E	E	E	E	E	E	E	E	E	E	E	LSt	E
M.N.A. West		E		E			E								
M.N.A. Nord		GSt	E											GSt	S
M.N.O. Brest		E			E			E						E/S	
M.N.O. St-Nazaire		E		E			E			E		E		E/S	
M.N.O. La Pallice		E												E/S	
2. A.d.U.	GSt	E	E	E	E	E	E	E	E	E	E	E	E	E/S	E
F.d.U. Norwegen		E/S												GSt	
M.F.S. Drontheim														E/S	
U.St.P. Kiel														E	
Norddeich				E	E		E	E		E		E			
M.N.O. Kiel				E	E		E	E		E		E			
U-Boote		GSt	E	GSt	GSt	E	GSt	GSt	E	GSt	E	GSt	E	GSt	E

Quellen: [31],[99]

Bezeichnungen:

Table 1
The main naval wireless stations (Leitfunknetz des B.d.U. 1942/43)[40]

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[39] I have been told by several U-boat signal men, that their 'Kommandant' refused to transmit at all (>late 1943). Fritz Deters of U-333 told me once, that his boat operated in 1944 for one month in British coastal waters, employing a so-called Schnorchel, by which means they were able to stay almost submerged. The 'Schnorchel' provided an air in and outlet. They were during that operation never attacked! It has to said, that they did not find a profitable target either! (which would have given away their likely existence) According Clay Blair - Cremer's boat U-333 was to monitor outgoing escorts and new sorts of radar signals. [13, p.583]

[40] M.N.O. = **M**arine **N**achrichten**o**ffizier; F.d.U. **F**ührung **d**er **U**-Boote; A.d.U. = **A**dmiral **d**er **U**-Boote; KW = short wave; LäW = VLF; E = receiving station; S = transmitting station; E/S = both.

Table 1, on the previous page, shows us what the most important stations were:
St. Nazaire – La Pallice (La Rochelle) – Trondheim (Norway) – Kiel and Norddeich. According to Wolfgang Hirschfeld's book [8] Kernével (Lorient) should also have been on this list. As it represented both the U-boat base Lorient and B.d.U. We can see, however, that on the list are several French (port) stations (the deeper implications of this list is not subject of this paper).

One does not have to study closely this table, as to get the impression that quite some wireless stations were involved in naval and submarine communications. When we keep in mind, that short wave communications are strongly influenced by daily and seasonal changes owing to the behaviour of Heaviside layers (I myself would prefer to say Kennelly-Heaviside); it is evident that when a boat at a certain moment is trying to convey a message, that he never knows what the actual propagation condition is (sometimes heavily influenced by eruptions at the solar surface). The most effective procedure was, and today still is, to listen into regular naval traffic. The station best heard is then selected and should be called for. Which might have been a station that is to bridge the longest distance (most far off).

German submarines used various kinds of messages (traffic). The header of a message enclosed the kind of traffic, like, for example – WW or ββ, the latter known in Britain as B-Bar for short enigma message. Derek Wellman, who was a wartime huff-duff operator (H.M.S. Onslow) and who also contributed to my book [7], gave me the following example: the (German) costal station made it clear that he is ready for listening in for new calls – a submarine sends **-…- -…-** (twice, dash dot dot dot dash, which is Morse-code for the Greek character β), the shore operator replied with **-.-** (= K means OK go on). Now the submarine operator sends his short message, like:

xxx (serial number in clear text, see table 3 and explanation below)
ββ
cfk
jbak
kqxu
cpy
cfk

The total time that the submarine was on the air lasted only for up to, say, 15 seconds! WW, thus weather messages, took only a bit longer, but not too much. [7, p.172- 179] It has, however, to be said, that standard enigma messages could take a much longer time on the air[41].

All these kinds of messages were regarded to be of most importance.

How could Allied intercept stations (also known as Y-stations) DF and/or listen into such short lasting signals (it might even have been doubtful, that owing to wireless propagations or 'skip', these signals would have reached them)?
Now a very important aspect of German naval communication has to be dealt with. Let us bear in mind, messages had only to be transmitted when their content was important in respect to warfare. U-boats should only communicate compact messages where possible. How could

[41] Y-stations and huff-duff operators had only to monitor costal (station) frequencies, as boats were always tuning zero-beat at these frequencies. Procedure known as 'in der Schwebungslücke' (neglecting later practices).

they know (being sure) whether his (coded) message was well received by the shore station, as the receiving side did not actually knew what its (instant) content should be?

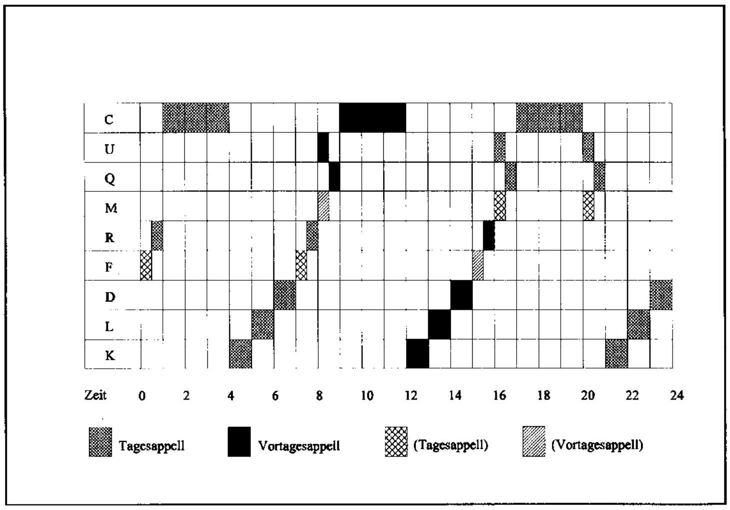

Table 2
Schedule table of daily enigma message recurrence (Appelle)

Their standard solution was, that these kinds of messages[42] were (integrally) repeated on various frequencies, be it on VLF (LäW) and on short waves (KW). And, they were repeated periodically until the U-boat had sent a confirming message (a time table could predict the repetition schedule), when no response occurred even for more then 24 hours or longer. One did not know whether a submarine had been able to listen into it yet, as it might have been engaged in tactical silence. These were the (most likely) signals that was intercepted in Britain and sent to Bletchley Park! The Germans used huge VLF transmitters like: Kootwijk (NL) – Base-Lande (FR) – Nauen and Goliath (both DE) (omitting others). Goliath (1 MW) signals could be received, when being fully sub-merged, even in the Straight of Singapore! [7, p.165-168] (of course not when being too deep) (notice Fn2 'Huff-Duff'→ 'Goliath')

These kinds of replying signals were known as "Tagesappell – Vortagsappell, which stands respectively for message of today and yesterday's message reply.
The advantage of this system was manifold. U-boats could be kept submerged when appropriate, but there was another spin-off. Fellow boats, even being in other areas, could also read what had been communicated. For them they could notice what was going on elsewhere. Wolfgang Hirschfeld told me once, that his submarine commander (Heinrich Bleichrodt of U-109) was always very keen to know what fellow boats were messaging. B.d.U. forbade direct message exchange between U-boats entirely. The German naval wireless interception service, known as X-B Dienst, monitored most U-boat communications for wireless violations too. When they discovered that boats had communicated by-passing B.d.U., then harsh troubles arose.
However, when the repeated signal had proved to be received correctly, boats should mention this in a next message (or mixing it into another one).

According to M.Dv.922, they gave very clear instructions as to how to anticipate when a message had proved to be corrupted. It was strictly forbidden to send the same message again(now in a new machine setting)! The message should be changed (reshuffling its content

[42] WW Obs. (weather report) messages were never repeated.

and/or shortening it when possible) such, that it got a different group number, so that the enemy could not directly reckon that it concerned the same massage.

Nanni 1 - 100	Niobe 1 - 100	Ost 101 - 200	Mittelmeer 501 - 600
Küste 1 - 100 Angers	Irland 101 - 200 Angers	Amerika I 201 - 300 Angers	
Amerika II 301 - 400 Villecresnes	Amerika III 401 - 500	Afrika I 501 - 600 Villecresnes	Afrika II 601 - 700 Villecresnes
Afrika III 701 - 800 Bernau	Diana 801 - 900 [a] Bernau	Hubertus 901 - 1000 Bernau	Wotan Bernau
Nordmeer I 601 - 700 Narvik	Nordmeer II 701 - 800 Narvik	Bruno [b] Norddeich	DAN "off" [c] Norddeich

Table 3

Serial numbers to the various 'Funkschaltungen' (Leitnummer). Enigma messages started always first with a serial-number in plain text

One additional remark should be made. When the shore station was being called and an enigma message was to be sent, the shore operator gave it, before giving allowance to the submarine (valid for all naval traffic) that he could start sending, an additional so-called "Leitnummer" which is a (daily) serial number. Often between 1 – 100. These serial numbers (of groups) were linked to certain divisions as can be noticed in table 3. The advantage was, that from the header one could recognize who had handed out the serial number. Please bear in mind, that after the shore station operator gave permission to some one that he could start passing on his message, he gave the serial number (Leitnummer) in plain text first (every message begun thus with a (clear) serial number). No mistake was possible. The replied message (Appel) still carried this (essential) Leitnummer.

In the available literature, one hardly will find records as to how HF/DF (huff-duff) was actually being handled, when an anti-submarine battle was emerging. Thanks to British PRO, we can have a closer look into what actually happened during the famous battle on ONS 5[43]. We consider, for this occasion, my reproduction of the records made by H.M.S. Pelican, starting on 6 May 0038 up to that same day on 2218 hours. [10]
Please be aware, that H.M.S. Pelican could only monitor two different frequencies at the same time, and that other DFing ships might have listened into other communications handled on different frequencies (maybe KWc and /or KWd), as many submarines were involved in this significant battle.

[43] ONS 5 covered 41 merchant ships and 7 (some say 9) escort vessels. B.d.U. lost 7 U-boats within a few hours! That month alone B.d.U. lacked 41 submarines! This is regarded the change (defeat) in U-boat warfare, since Dönitz abandoned most offensive operations in the Atlantic. Waiting for new boat types (XXI series) and tactics.

Secret Sheet 1

H.M.S. Pelican H/F D/F Bearings 5/5/43 to[29]

Date	Time	Freq.	Position	Type	Bearing	Remarks
6/5	0038	7647	50 33 N 45 39 W	B̄	006	B̄B̄ WON IWGF KV
6/5	0048	7647	50 33 N 45 39 W	B̄	001	Weak signal B̄B̄ GRZ ECTA PCAT PTIB
6/5	0050	7647	50 33 N 45 39 W	NE	007	0205/6 Weak signal
6/5	0058	7647	50 33 N 45 39 W	B̄	016	Good strength B̄B̄ BFJ HUIG WTGG FKEB
6/5	0110	5650	50 48 N 45 36 W	NE	019	Good strength Naval Enigma
6/5	0148	7647	50 48 N 45 36 W	B̄	021	Poor signal B̄B̄ PAL QQQB VXNV YA
6/5	0201	7647	51 02 N 45 37 W	NE	020	Good minima Naval Enigma
6/5	0242	7647	51 02 N 45 37 W	NE	018	Naval Enigma
6/5	0322	7647	51 18 N 45 41 W	NE	002	Good minima 0501/6 29 OECI FNQL
6/5	0417	7647	51 35 N 45 20 W	NE	325	Fair signal 0607/6 37 XTBK SZIW
6/5	0424	7647	51 35 N 45 02 W	NE	021	Fair signal 0610/6 34 CTZP MJMK
6/5	0447	7647	51 45 N 45 17 W	NE	023	Fair signal 0632/6 22 SSRD OSPR
6/5	0458	7647	51 47 N 45 17 W	NE	325	Good strength 0645/6 21 QEIX HCGH
6/5	0512	7647	51 45 N 45 17 W	NE	338	Good minima 0646/32 32 etc.
6/5	0549	5560[30]	51 45 N 45 17 W		325	Not identified
6/5	0645	7812	51 45 N 45 17 W		353	4 Letter code
6/5	0914	10525	51 45 N 45 17 W		335	Good bearing ????
6/5	1131	12215	51 34 N 45 27 W	NE	024	Good strength 1159/6 45 etc.
6/5	1220	12215	51 28 N 45 23 W	NE	300 120[31]	Weak signal 1355/6 32 etc
6/5	1235	12215	51 27 N 45 23 W	WW	050	Fading signal WW NZN etc.
6/5	1350	12215	51 29 N 45 28 W		010 190[32]	unidentified
6/5	1405	12215	51 17 N 45 28 W	WW	045	Loud signal WW KCTS YLGN
6/5	1409	10525	51 17 N 45 25 W	NE	030	..49/6 etc.
6/5	1420	10525	51 16 N 45 31 W	NE	042	Good bearing
6/5	1428	12215	51 16 N 45 31 W	NE	005	Loud signal 1600/6 35 K..T
6/5	1448	12215	51 13 N 45 31 W	NE	035	Good bearing 1840/6 etc.
6/5	1511	12215	51 11 N 45 32 W	NE	072	Good strength 4 letter code
6/5	1701	12215	50 45 N 45 27 W	NE	001	Ground wave 1840/6 etc.
6/5	1705	12215	50 45 N 45 27 W	NE	052	Fair strength 1815/6 72 etc.
6/5	2218	7647	50 03 N 45 39 W	NE	034	Good bearing 1927/6 73 WJSQ

Table 4

HF/DF (huff-duff) reports originating from H.M.S. Pelican, taken on 6 May 1943, during the famous (decisive) battle on ONS 5.

Let us notice what is mentioned:

Date	6 May
Time	0038[44]
Frequency	7647 kHz
Position of H.M.S Pelican	accurate map coordinates
Type	B-Bar
Bearing	the bearing against ship's forward (F)
Remarks	ββ part of the message intercepted or DFed on

Let us jump now to line 5

The main difference is, that the actual frequency has changed to 5650 kHz. When we go back to table 1, we see that the columns Amerika I and Amerika II mention four waves KWa – KWb and KWc - KWd. The application of two different frequencies, to know 7647 and 5650 kHz, might be equal to KWa and KWb[45]. During daytime, thus when the sun is above the horizon, they moved to higher frequencies 10525 and 12215 kHz. Which for that time of the day may also represent KWa or KWb, as well.

During evening/night time they returned again to a lower frequency spectrum. It has to be clear, that a submarine always tried first to listen for (trying to receive) his home base station, say, Kernével and when their signal was interfered or could not sufficiently good received (or was busy), then another shore station has to be looked for, being free (not busy) or having the best signal.

---

[44] BP mentioned in this case TOO, which stands for **t**ime **o**f **o**rigin. BP adopted fully German 24 hour notations.

[45] KW = Kurzwelle = short wave.

The changing behaviour of frequencies versus time of the day is very well known by short wave radio amateurs (Hams).

Coastal shore stations carried always call-signs with an "Umlaut" (diaeresis, two dots over a character). For example, widely heard were: JXÄ for F.d.U. West (maybe handled by Kernével); Berlin control ÄDA; Kernvel (Lorient) used RXÜ and Wilhelmshaven (Sengwarden) KYÜ. DAN was Norddeich Radio, they did not use a Kriegsmarine call-sign designation, although, they played a very important role in (long distance) naval communications.

To close this section, I would like to show an example of a real enigma message (German known as Schlüssel M4), which was intercepted by H.M.S. Hurricane on 25 November 1942. When Bletchley Park was still blind to de-code any four wheel U-boats messages (Schlüssel M4), since 2 February 1942. [7, p. 169-171] One hardly will find such source text, as PRO (mainly)does have their (translated) decrypts.

```
FCLC QRKN NCZW VUSX PNYM INHZ XMQX SFWX WLKJ AHSH NMCO OCAK
UQPM KCSM HKSE INJU SBLK IOSX CKUB HMLL XCSJ USRR DVKO HULX
WCCB GVLI YXEO AHXR HKKF VDRE WEZL XOBA FGYU JQUK GRTV UKAM
EURS VEKS UHHV OYHA BCJW MAKL FKLM YFVN RIZR VVRT KOFD ANJM
OLBG FFLE OPRG TFLV RHOW OPBE KVWM UQFM PWPA RMHF AGKX IIBG
FCLC QRKM VA
          T.O.R. 1840/19Z          (62 groups)
```

Genuine enigma message interception, taken by operators onboard H.M.S. Hurricane, on 25 November 1942.

T.O.R most likely means: time of reception. VA is curious, as in Morse-code it is:
...- .- but, when you read it differently, as the Germans actually meant – it becomes **... -.-**
Which means SK and stands for 'end of transmission', this code is still valid[46].
Ralph Erskine, who also contributed largely to my book, sent me some time ago an e-mail message that computer simulations had, after all, broken the content of this message. Please notice, that the origin of this message is straight received from a U-boat signal.

Very typically for these kinds of messages is, that they all (should) start and end with two equal character groups. The first one passing on settings information (key or Schlüssel) – the second four characters providing the actual wheels (rotors) starting positions.

Finally

Was Enigma a secure system?

Theoretically one must say – yes it was. For as long as the message is short and there is no clue for what its content might be, and the machine setting is truly random! This is, by the way, true for most good coding systems of the 1940s.

[46] I guess, it meant "**s**ilent **k**ey", radio hams use this expressing for some one who has passed away.

Let us consider the calculations made by the Dutch Navy Service Section MEOB (Oestgeest) and which was shown during an 'open day' in the 1980s.

<u>Die Möglichkeiten der Enigma</u>

angegeben ist die Zahl der Tauschmöglichkeiten (Buchstabentausch)

a. Das Steckerbrett

Zahl der Möglichkeiten mit n Steckerverbindungen nach der Formel $26!/[n!\cdot(26-2n)!\cdot 2^n]$

Steckerverbindungen (n)	Tauschmöglichkeiten
0	1
1	325
2	44.850
3	3.453.450
4	164.038.875
5	5.019.589.575
6	100.391.791.500
7	1.305.093.290.000
8	10.767.019.640.000
9	53.835.098.190.000
10	150.738.274.900.000
11	205.552.193.100.000
12	102.776.096.500.000
13	7.905.853.580.550
0-13 Steckerverbindungen	532.985.208.200.000

b. Die drei Tausch- oder Schlüsselwalzen

Zahl der möglichen Reihenfolgen beim Einsetzen
- bei Auswahl aus einem Satz von 3 Walzen 6 Möglichkeiten
- bei Auswahl aus einem Satz von 5 Walzen 60 Möglichkeiten
- bei Auswahl aus einem Satz von 8 Walzen 336 Möglichkeiten

Zahl der Möglichkeiten beim Einstellen der Grundstellung
- bei einem Satz von 3 Walzen 17.576 Möglichkeiten

c. Die vierte Walze beim Marinemodell (=Schlüssel M 4, 1942-45)

Zahl der Möglichkeiten
- bei Auswahl aus einem Satz von 2 Walzen 2 Möglichkeiten
- beim Einstellen der Grundstellung 26 Möglichkeiten

*

Die Zahl der Tauschmöglichkeiten, mithin der Schlüssel, betrug danach für die <u>Normalausführung</u> der Enigma, wie sie von 1938 bis 1945 beim Heer Verwendung fand, mit einem Satz von 5 Walzen und Schaltung von 7 bis 11 Steckerverbindungen:

60 (Auswahl aus einem Satz von 5 Walzen) mal 17.576 (Einstellen der Grundstellung) mal 422.197.679.120.000 (Schaltung von 7 bis 11 Steckerverbindungen), also insgesamt <u>445.232.784.600.000.000.000 Möglichkeiten</u>.

*

Die Zahl der Tauschmöglichkeiten, mithin der Schlüssel, für die <u>Marineausführung</u> der Enigma, die unter der Bezeichnung Schlüssel M 4 von 1942 bis 1945 Verwendung fand, betrug dagegen mit einem Satz von 8 Walzen, der zusätzlichen vierten Walze und Schaltung von 7 bis 11 Steckerverbindungen:

336 (Auswahl aus einem Satz von 8 Walzen) mal 17.576 (Einstellen der Grundstellung) mal 2 (Auswahl der vierten Walze aus einem Satz von 2) mal 26 (Einstellen der Grundstellung der vierten Walze) mal 422.197.679.120.000 (Schaltung von 7 bis 11 Steckerverbindungen), also insgesamt nicht weniger als <u>129.651.786.900.000.000.000.000 Möglichkeiten</u>!

Table 4.

Calculations showing the maximum possible key variations of a 4 rotor (wheel) enigma (Schlüssel M4)

Please notice: Walze means wheel (rotor); Möglichkeiten means possibilities; Steckerverbindungen means plug board permutations

The final figure at the bottom of this table gives:
129,651,786,900,000,000,000,000 possibilities! > 10^{24}
We may conclude that this is an enormous figure. But, why did it went, nevertheless, wrong?

Briefly, an important aspect is, always, the human factor - and the stringent military hierarchy, discipline and procedures. For example, an officer should be talked to politely and according strict military rules, like - Jawohl Herr Leutnant, or Jawohl Herr Kapitän. So is it understandable that the frame of messages were strict and inflexibly being maintained[47]. This strictly formal military information exchange was one of the golden grips by which means the BP cryptologist could approach messages. Secondly, the submarines were forced to use all in a certain period of the day and war theatre (Schaltung) the same basic machine settings, be it, with some individual pre-settings[48]. But still, the system was organised in such a rigid manner, that on the other end of the line they should be able to deduce the correct starting point of settings.
We have also seen, that coastal (shore) stations had to handle various kinds of traffic, not knowing in advance what machine settings were valid for a particular message (including 3 or 4 wheel machines). This was, of course, also true for army and GAF enigma messages. The implication was, that a huge organisation was involved and that on hundreds maybe even several thousands places should they be able to de-crypt an enigma message. Consequently, each organisation had to possess, at all times, all coding materials valid (for them).

One may ask why haven't the Germans deployed "one time path" coding procedures? In my opinion, because it would not have worked.
Regard - Bletchley Park decrypt at the end of the war hundred thousand messages per month[49]. How could the Wehrmacht ever cope with 'one time path' coding materials, being supplied to all responsible organisations, for sometimes several months in advance? A submarine could be, for instance, at sea for even half a year or longer.

Admiral Dönitz had, however, several times (1943/44) very strong doubts on the security of enigma. But all the time German experts pointed after due investigations, that their Schlüssel M was secure and could not have been breached (decrypt). Again, an example of arrogance and human failure, as we know now.

In Britain hardly noticed is - that American OP-20G, which equalled Bletchley Park, did a considerable job on breaking enigma codes as well. According Michael Smith and Ralph Erskine's book 'Action this Day' - *British designs for four-wheel bombes were running into difficulties in particular in getting the high-speed rotors to make good electrical contact … The US Navy's 100 four-wheel bombes* (all made by NCR, AOB) *operating in Washington largely took over the entire job of decrypting the U-boat traffic, codenamed 'Shark', by autumn 1943. The British for-wheel bombes, by GC&CS's own admission, had never functioned as intended, and on 24 March 1944 GC&CS cabled to Washington conceding the four-wheel bombe field to the Americans. In fact, the US Navy bombes worked so well that by spring 1944 they had huge, excess capacity in spare. Not only were they handling virtually all of the U-boat traffic; about 45 per cent of the US Navy bombe time was being devoted to*

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[47] Generally, the main break-troughs were basically owing to purely human failures, after procedures were violating comprehensive security instructions! In my view, that the Germans for some time could read (breaking-into) British military codes, might also originate from failing British (wireless) procedures.
[48] When the war started naval-enigma-settings changed ones a day, successively twice … and then four times a day, thus machine settings changing every six hours!
[49] One must be aware, that most, I guess >> 90%, was of no direct sense. For instance, the occupying force of Guernsey demanded the naval depot in Cherbourg, to send them some transmitter valves for replacement. These kinds of messages were probably the bulk of what had to be accomplished at Bletchley Park. Of course, one always had to watch (monitor) for golden tactical or strategic clues.[11]

German Army and Air Force (GAF, AOB) *problems being cabled from GC&CS. …* [12, p.211- 325]

That the secrets on Bletchley Parks´ involvements in breaking Germany's enigma codes could last for such a long period, might, in my view, very well (also) originate from the bold British publications of the early 1920s, where the work done at 'Room 40' of the British Admiralty was revealed[50]. The German Navy (Reichsmarine) was embarrassed and since then aware of the breaking of their naval codes during most of World War One. They were therefore very keen to do it this time better. And, because no one was sure then that the Germans never again would oppose a future thread (enemy) again, that the likely decision was taken that this time no one should know what was achieved in breaking into enemy codes.

VI. Conclusions

We have noticed some aspect of German communications. After reading my (brief) retrospective, one might like to know – did it all work well and possessed the Germans really adequate communication facilities? Yes, it did. Though, since, say, early 1944 the ratio 'radio per *capita'* was far in favour of the Allied forces[51].
Neglecting, for this occasion, the disastrous implications of Ultra.
It has to be noticed, nevertheless, that when the war would have dragged on much longer, that after time (most) BP bombs might have become redundant[52]. Two examples, the blow of the Ardennes Offensive (Battle of the Bulge), for was not predicted by Ultra at all! Hitler personally had decided that in this matter, all communications related to this operation, they should not deploy wireless nor telephones at all[53]! A second, not often mentioned aspect is – that in 1945 (some) U-boats operated in the North-Sea, whereas Bletchley Park could not provide the decrypts. The reason was, that these used "one time path" machine settings. [7]

Albeit, let us now follow the course of history. As has been pointed, the Germans started about, say, 1934/36, to develop new military communication gear. These systems were, in the days of their conception, state of the art. Reliable – versatile – consuming relatively low energy – fairly small sized – and very handsome during their application and maintenance in the field. In Britain and probably also in the US, Army did not have comparable concepts. There is no doubt about it. The diversion (upgrading) started after the war broke out. Both, in Britain and America, they were forced to develop new communication systems. In their days,

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[50] Among this, the chief of the British secret service during the war, Admiral William Reginald Hall, declared in a very interesting speech (held) at Manchester in 1920 that - the decipherment of the Zimmermann telegram had decided the World War in favour of the Allies. [5, p. 45]
[51] Their main intension was focussed on replacing the maximum quantity of fighting gear, like: new automatic assault rifles (Sturmgewehr 44), tanks, anti-tank weapons such as Panzerfaust, Ofenrohr (both kinds of Bazookas), fighter aircraft, and so forth.
[52] There existed a German alternative to enigma coding machines, and that was: Schlüsselgerät SG-41, nicknamed "Hitlermühle" (Hitler-mill). See: http://jproc.ca/crypto/schluesselgeraet_41.html and http://jproc.ca/crypto/menu.html They lacked, however, the industrial and organisational capacity to replace the > 100,000 existing enigmas. The SG-41 principle worked on the line of the Hagelin machines like type M 209, which was deployed by American forces quite some time after the war. Consider the corresponding URLs. It is most likely, that sooner or later this latter system was also 'crushed' by mechanical or electronic means!
[53] Even premature reconnaissance on the entire frontline was prohibited!

of course, the best the nations could provide, regarding their resources[54]. In this respect the Americans possessed the advantage of having a huge industrial potential, and they could design soundly with lavish use of relatively scare materials. Whereas Britain had to provide what they had at hand. Such as, for example, using Fe instead of Al and so forth.

An, in my view, very important point is, that there is always - **the disadvantage of being (once) advanced!** Thus, when some one starts at a certain time to deploy new technologies, they cannot simply change the system even when better technologies are at hand. Military systems have often to last for a considerable time (a decade or much longer). For example, when WS 19 was introduced it was a versatile well purposed set. We can not say that it was 'state of the art' in the 1950s[55]. Or, look at the British 1935 TV system utilizing 405 lines, up to the 1960s[56]. Similarly occurred with German concepts, designed about mid of the 1930s, but it was well realized that after say 1941/42 there was a growing demand for (some) new concepts. Though, how could they cope with – wasting still workable apparatus and not possessing even the resources to replace them materially? This process proceeded step by step and vanished towards the end of the war. After mid 1943, all kinds of improvisations had to be accomplished as to get the necessary devices they desperately wanted. (regard Fn 2, on 'German Airborne Radar') The Germans faced more and more the down-side of their comprehensive apparatus design, as its production demanded far too many skilled labours and valuable time was lost by its manufacture. Particularly in respect to its often very short lasting life-cycle.

Reflection

I would like now to point at a facet that not often is associated to wartime history.

If we leave out the direct war engagements, there is another very significant point which has to be considered, and that is – the complete absence of a form of "democracy". When we look back in history, even the recent one, then there is one striking aspect and that is - **that prosperity on the long run can only being achieved, when a state is democratically governed**. Look, for instance, to the Netherlands in the seventeenth century, where they established world's first multi-national "VOC" (Verenigde Oost-Indische Compagnie), since 1604. One might say, hold on, in those days they did not have real democracy. That is to some extent true, but there existed a fairly kind of freedom to (jointly) decide commercially on business facts only (entrepreneurship)[57] hence, decision was not based on dogmatism (state canon). France, under Napoleon Bonaparte was doomed to fail, as what mainly counted was Napoleon's dogma. An example of our recent past – look to what happened to the communists in Russia and Eastern-Europe, during the previous century. All failed to gain prosperity. China would have been trapped in the same manner, should it not have changed the way in which decisions are being engendered, although, they still have a (very) long way ahead.

Last but not least, the best example is Britain!

[54] Another point of consideration is, that technology had generally improved rapidly, since, say, mid 1930s. Hence, four to five years of technical innovations may be regarded like a "quantum leap"!

[55] H2S like radar set was still deployed during the Falkland war!

[56] The odd US 115 volt mains power (line) system goes back to the (midlife) days of Thomas Edison.

[57] To some extent, the great achievements of the Roman Empire may also be regarded an example, including their ultimate (imperative) decline.

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