Synopsis

Some aspects of military line communication as deployed by the German armed forces prior to 1945.

A retrospective concerning military communications is, in some respect, of significance to those people who are interested in wartime history. Most people seem to think that wireless communication was the main and perhaps even the only way to communicate over distance. This idea prevailed despite the fact that everybody is acquainted with the application of the telephone in every day life! Its importance for military operations is still rather underestimated and it is regrettable that the importance of line linked communications is still a neglected theme by historians.
The aim of this paper is to enhance the understanding of some of its aspects, to explain how the Germans used this medium and, to explain some of its technical and historical facets.

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Introduction

The semaphore was, in the past, a signalling system which allowed, (even in the days of Napoleon) the rapid conveyance of messages. A disadvantage was that it could only be used during (clear) daytime and that quite a comprehensive service had to be maintained to keep this system operational. Since the early days of this century "telephony" was becoming of more and more significance for the civilized world, and most major cities and places were connected (linked) together. For long distance communication Morse telegraphy, by line, was still the backbone of data transfer. Notwithstanding that all sorts of semi-automatic systems were designed to enhance the quantity of data transfer, the lack of adequate technology such as (for instance) electronic amplifiers, limited its technical application.

The First World War can be seen as the first period in history in which telephone and wireless communications, especially for military operation and tactics, became of the utmost importance. Consequently, the very demand for all kinds of communication aids forced the telephone and wireless industries to step-up production and to re-design their apparatus to meet the military requirements and demands. Most Post organisations (PTT, BPO, ...) (see also list of abbreviations at the end of this paper) were, in many respects, being run in the usual bureaucratic manner and consequently not responding fast enough to adopt new technology.

However, military operational requirements are, from their very nature, rather different and improvisation is of great relevance. Progress was hampered by the lack of understanding of the possibilities of modern communications methods, not only by those in senior position in the German army but in other armies too. Praun mentioned in his book an illustrative

anecdote which happened on the western front during the first minutes of New Years Day 1916: - *He handed over the telephone to his commanding General to let him listen to the regards of his man in the trenches. He stated that he couldn't hear anything, probably due to a technical failure.* Praun's comment of this event was *"This was probably the only event in which this highly ranked* (old) *man had come into touch with communication technology.* (1, p. 16)

In the first month after the German invasion of France in 1914, wireless communications were extensively used by the Germans. Certainly the lack of adequate organisation, discipline and security permitted the French to counter most German tactical operations, which finally culminated in the "Miracle of the Marne", where the German military progress on the western front was ultimately stopped. After this turning point in history, the western front began to stabilize and the construction of telephone facilities increased day by day on both sides of the front line. (2, p. 16-18)

As an example I have selected **one** aspect of wire communication which had a great impact on the course of the First World War.

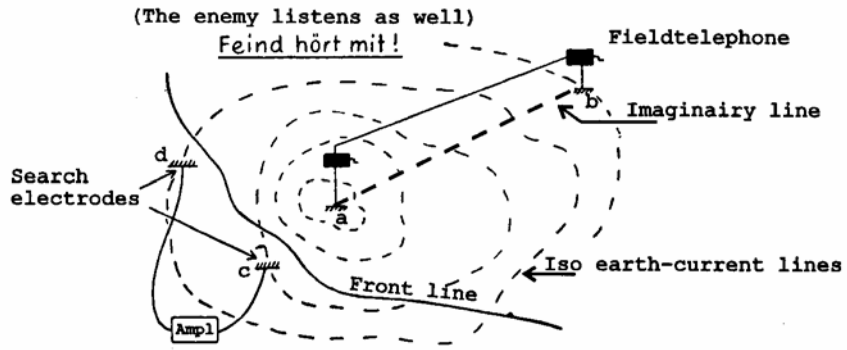

Figure 1: The danger of using the ground in a return circuit

To economize on the construction of telephone lines (wire), most short distance lines were asymmetrically built, so that only one signal wire had to be deployed and the ground (earth or soil) was used for the return circuit.

Its simplicity of deployment and operation is obvious, but from the perspective of security such a telephone circuit was a real nightmare. All belligerents were employing so-called "search electrodes" which were stuck into the ground to look for any kind of modulated electrical earth currents.

The return current in figure 1 between the points a and b is not flowing just between these two points in a straight line as, due to the conductivity phenomenon of the ground (soil), the current is passing through a much wider area than would at first be expected. By means of so-called search electrodes it was possible to pick-up some part of the electrical current between the electrodes c and d as well (sometimes additional electrodes in several directions were stuck in to the ground to look for the optimal reception). In fact what was measured was the voltage drop, due to the specific conductivity of the ground. The further these electrodes are placed from the imaginary centre line a - b, the weaker is the signal that can be intercepted. Near the line a - b the signal can be picked-up by a regular sensitive version of a trench or field telephone however, it is quite likely that the enemy was, in most cases, not positioned on

or near this imaginary line. To overcome this disadvantage the Germans introduced, for the first time in history, AF valve amplifiers to increase the level of the intercepted signals. Its success was apparent but, as could be expected in a war, sooner or later the French found out about it and rapidly adopted this interception method themselves on an extensive scale.

It is hard to believe that, although both belligerents knew about the danger of being intercepted by these means, they still continued to maintain very insecure communication procedures. (3, p.15-39) This was probably due to the fact that most people were, in those days, not yet sensibly acquainted with the nature of such instruments.

During "Interbellum"

In the 1920s military line communications were becoming, in most cases, a matter of using the regular telephone facilities because these were easy to handle and to maintain as well. Long distance (telephone) communications were becoming daily practice. WW I had boosted the development of valves and, in most developed countries of the world, all sorts of related technology.

From the early 1920s onwards, long-life valves (so-called "Poströhre *or* Weitverkehrsröhre") for telephone repeaters and amplifiers were introduced in Germany by the Siemens company (type BA, BO, CA,...) which allowed a life cycle of > 10,000 hours. The German "Reichspost" (abbreviated DRP, which was equal to the British PO) started to built automatic telephone exchanges in the great cities like Berlin, Munich, etc. Although the extension and modification of the German telephone service wasn't completed before the Second World War started, most places were linked via automatic telephone exchange facilities.

The widespread adoption of carrier telephony (see later) enhanced the efficiency of the available telephone lines and cables. The occurrence on the market of very new technologies and components such as - long-life valves, piezo-electric vibrators (quartz oscillators), the improved iron dust-cores for filtering and pupin-cores (loading coils) and copper oxide (semiconductor) rectifiers to built ringmixers, improved the wide spread implementation of (carrier) telephony in general.

In Germany there were two main streams - the military service and private enterprises. Both of them were working in their own way. The military organisations, for obvious reasons, were building up their own facilities as were also the telecom industries. The German "Reichspost" was, in the first place, extending its network and services and not directly acting in cooperation with the military complex. A similar state of affairs existed in industry! At the outbreak of the Second World War the "Wehrmacht" tried to get full control over the resources of non military organisations. Stocks were, when possible, controlled (or even confiscated) and the German "Reichspost" became more and more like a kind of employment agency, which had to hand over personnel and provide all sorts of facilities.
The German armed forces relied, to a great extent, on the regular telephone network of the Reichspost and only in areas which were designated as "defence zone" did they mainly rely on their own signal organisation called "Nachrichtenmitteltruppe" (Signal Corps or troops).

Technical aspects of line communications

At this point let us take a very brief look at some of the technical aspects of "telephony over line" which was, more or less, the "state of the art in Germany" up until the 1940s (in some respects even very much longer as, presumably, was the case in most other civilized countries too)!

Between the wars there were two main ways of transferring telephone data, those were - cable and open wire systems (coax cables like the so-called "Styroflex cables" were often employed for some strategic trunks, though they were still an exception). Cables were basically deployed in city areas and the permanent air-line systems (hereafter called air-lines) were more often used in the countryside because those were inexpensive to erect although quite vulnerable to environmental influences and, of course, in danger of being struck by lightning. An advantage was that air-lines allowed a much better signal transfer over distance (see below) due to their very low power loss, as compared with regular telephone cables.

According to a German army instruction table (4, p. 3) it can be estimated that, for different types of telephone cable or air-line without additional amplification, the audibility (readability) can be qualified **good** for distances up to:

- FFK (equivalent to the American "spiral four") 50 km
- FD 1.5 mm (1.5 mm bronze open land-line) 120 km
- FD 2.0 mm (2.0 mm bronze wire) 200 km
- FD 3 mm (3 mm bronze wire) 425 km

FFK = Feldfernkabel = Field cable; FD = Felddauerleitung = air-line, spaced 20 cm, loss ≈ 0,0049N/km (Later in the war the FF cables were copied (adopted) and modified by the US Army and became well known as "Spiral four") (5, p. 241-242)

Most PO's in Europe expressed the signal power of telephone related technology in Neper. 0 N is, at 600 ohm, equal to 0.775 volt (1 mW) and +1 N = 2,106 V which is equal to 8.686 dB. (Neper is based on ½ times the "natural logarithm or ln" of the power ratio, whereas dB is based on 10 times the "decimal logarithm or log" of the power ratio) (6, p. 234) (7, p. 209)

To enhance the line capacity of telephone cables or lines, several different technologies could be used (for this paper we neglect the existence of PCM, ISDN and other sophisticated technologies).

Most telephone customers, even today, seem to have the impression that all signal transfer is maintained by a two wire system, which is (was) only true for that line section which is between the telephone set and the first amplifying unit (station). From here on the signal path was split into two system sections (using a so-called "fork-circuit" or hybrid transformer), and was then handled via a so-called "four wire" system. One pair of wires (cores) was used for reception the next pair was used for the out going signal. The reason for doing this is to avoid cross talk and echoing effect after multi-amplification. Only after the final interface (amplifier) was the four wire system converted back again into a two wire system, as was the situation on the other end of the line. Consequently, for each transferred telephone call four

wires had to be used. The Germans called each pair (2 + 2) "Stamm 1 and 2". This can hardly be seen as an economical mode of transferring telephone signals, if for each telephone call two line pairs were needed.

To overcome this disadvantage so-called "Phantom" circuits (see hereafter) were being used even in the early days (the German armed forces used the term "Viererschaltung or Kunstschaltung" which is translated "artificial circuit").

In figure 2 on the next page, let us consider the circuits (a), (b) and (c). Circuit (a) is to all intents and purposes similar to circuit (b) so I will comment only on (b).

In circuit (c) four users are connected on both sides of the line system (2+2) and these, theoretically, do not interfere with each other. This circuit (c) was sometimes used by the German armed forces when there was a lack of sufficient telephone lines during military operations. The circuit would not, however, be used by PO's who did not employ earthed systems in their long distance (regular) networks. In situation (b) we assume that both lines are perfectly matched in respect to their mutual length and capacitance against ground and to each other and that the transformer taps are correctly centred. In this case both wires of Stamm 1 and Stamm 2 are fed in "common mode" (both arrows are representing equal currents hence these currents cannot induce any current in the secondary side of the transformers) whatever the waveform of the signal current is.

To increase the number of signal channels which could be transferred via a telephone line or cable, telephone signals were modulated onto a RF carrier and this (modulated) signal was transmitted to and/or received from a similar station on the other end of a line (section). Each signal channel was using one side band of a suppressed carrier signal. This was explained for the signal path - station A → B and station B → A. (A - is receiving the lower side band and transmitting on upper side band towards B, whereas B - is receiving the upper side band and transmitting on the lower side band towards station A) (8, p.36)

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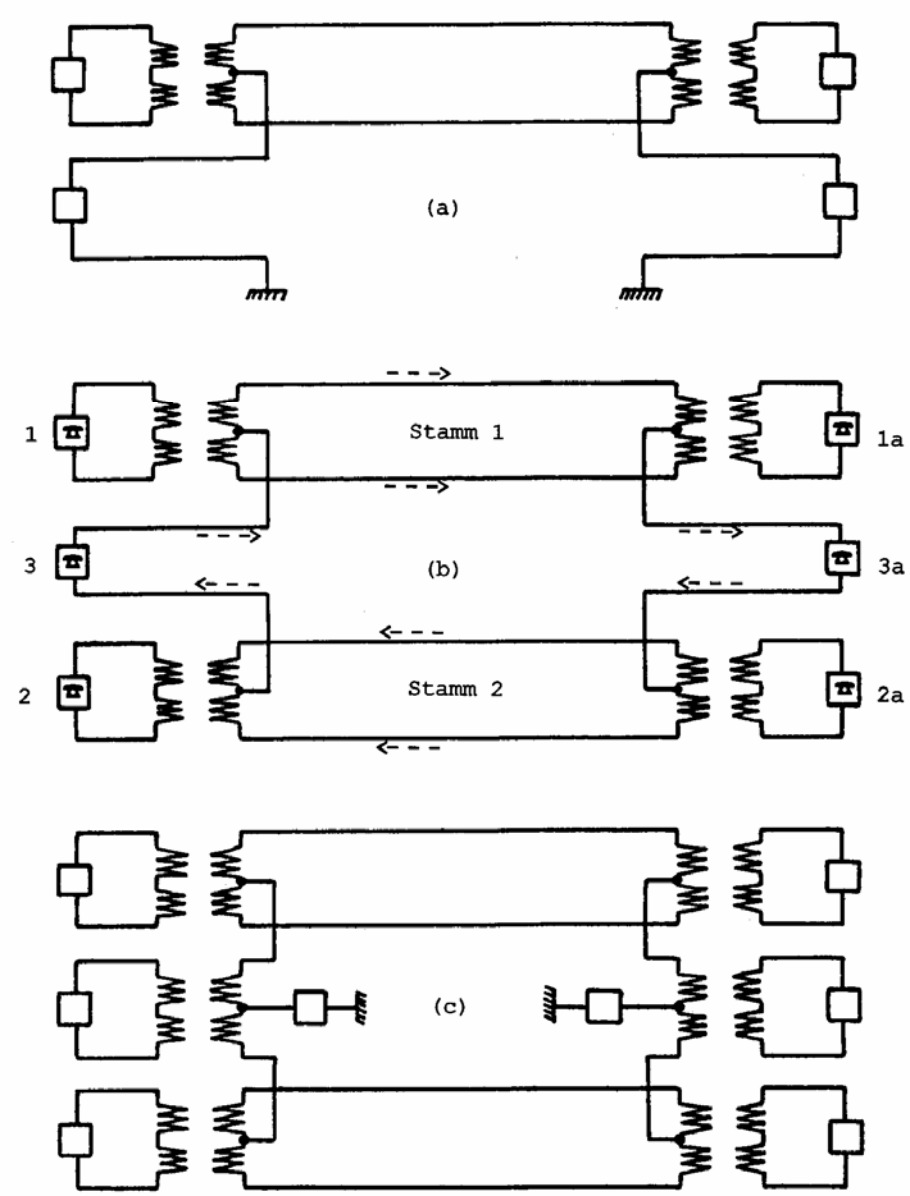

Figure 2: Examples of phantom circuits (Kunstschaltungen)

Both technologies, the low frequency and carrier telephony signal path, were commonly transferred via different type of cables. For this occasion we neglect the use of loading coils (in Germany known as "Bespulung" by means of "pupin cores") of telephone cables or lines, which on the one hand reduced the power loss for low frequency signals but, on the other hand, reduced the maximum carrier frequency which could be transferred. Basically therefore loading coils could not be utilized in conjunction with carrier telephony. Nonetheless, the German signal troops often used single channel carrier systems working on relatively low frequencies between 5 up to 24 kHz (TF a, b and TFb 1, 2, 3, 4) which were not seriously affected by lightly loaded lines (below 15 kHz carrier frequency).

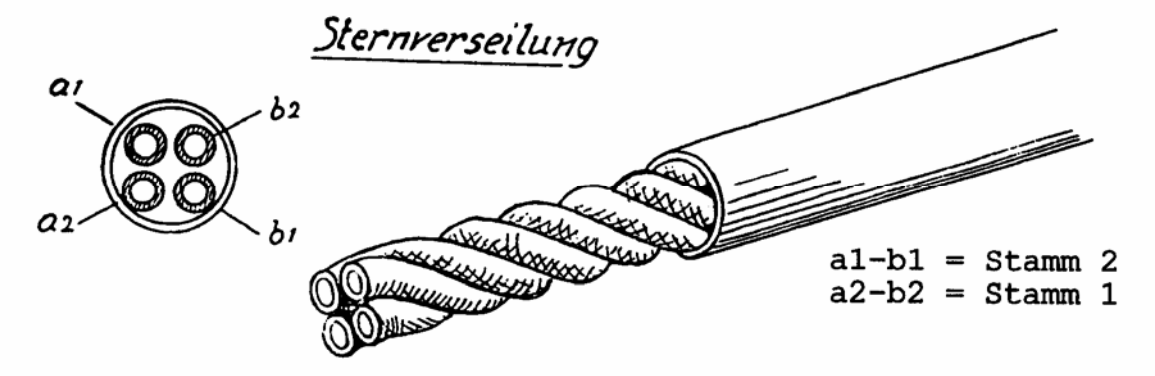

Figure 3a: Construction of the Feldfernkabel (FFK), equiv. spiral four

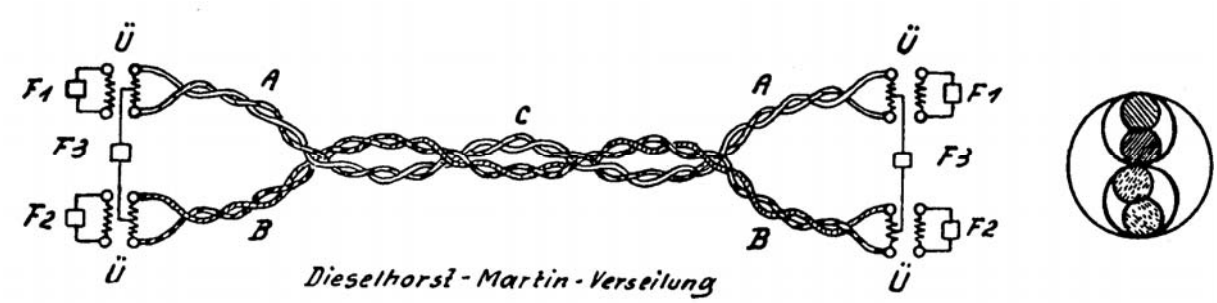

Figure 3b: The DM-cable, in conjunction with a phantom circuit

Basically we can distinguish between the cable types in figures a - b or combinations of these. Drawing 'a' show "Sternverseilung" which also became known as "Spiral four". Drawing 'b' illustrates the so-called "DM" cable type. (DM stands for: Dieselhorst-Martin)

The cable shown in drawing section 'a' consists of spirally twisted cores, which can form a four wire trunk (2 + 2). The opposite wires belongs to the same signal channel (Stamm). The advantage of this cable type is that the separation between the two wire groups is rather good and cross talk level is very low. But, a disadvantage is that when such a cable type is used in conjunction with a "Phantom" circuit the symmetry can't be assured, due to the vulnerability to slight changes in their mutual capacitances when, for instance, the cable has been bent.

Diagram 3 b shows the "DM cable". Each line pair is twisted with a specific pitch. The advantage of this technology is that of very low levels of cross talk but a disadvantage is the increase in the diameter of those cables.

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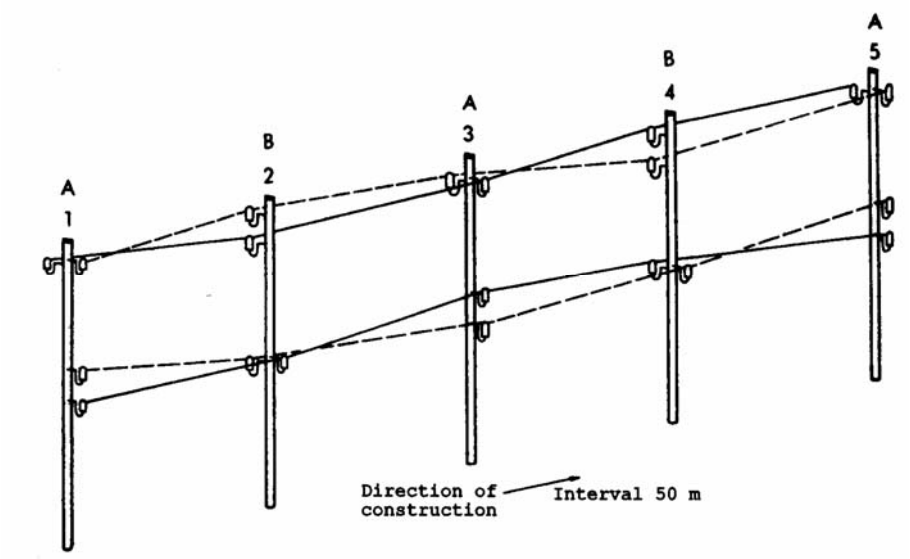


Figure 4a: Drehkreuzachse, consisting of two lines

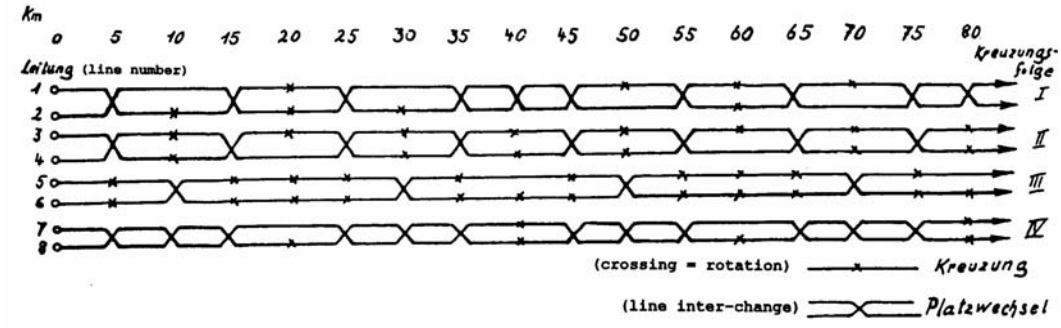


Figure 4b: Example of a “Drehkreuz” layout

It is known (from physics) that parallel wires can induce mutual currents. This phenomenon is especially a nuisance when signals are transferred over some distance on air-line trunks. The electromagnetic environment can also induce additional man made noise and/or interference. This could be countered, as is shown in fig. 4 a and b, by changing the mutual position of the wires and to spin (rotate, German "Drall") these individual line wires with respect to the other wire pairs at particular locations. The German army rotated the wire pairs (Stamm) in a clockwise direction, whereas the Luftwaffe maintained an anti-clockwise rotation. In Germany this technology (line type) became known as "Drehkreuzachse or Drehkreuzlinie" (Achse may be explained as "spill" and linie as "route"). Figure 4 b shows an example of an air-line layout. We see on the left hand side the Stamm or cable numbers and each Stamm consist of two wires. The individual line pairs are changing their positions in a certain sequence with respect to each other. The cross overs are similar to those shown in fig. 4 a. It doesn't matter if the lines are used in two or four wire systems (or a combination of both).

The technical term "Drehkreuzachse" seems to be completely unknown in Britain, because according to Hinsley in his book "the Inside Story of Bletchley Park": - *New technical terms sometimes gave trouble..... I can remember his* (Trevor Jones, AOB) *going round for several days with a worried look on his face murmuring "Drehkreuzachse"...*) (9, p. 21)

According to a technical reference (4) (8) the sequence and point of rotation has to be maintained within a limit of < 1/10 λ of the specific signal frequency which is to be transferred. Low frequency (near DC) signals as used for regular telephone could be rotated every 25 km, something of a nuisance when carrier signals of the Siemens MG 15 apparatus had to be handled which used up to 150 kHz (λ=2 km), then every 2000 : 10 = 200 m a line rotation had to be deployed. The MG 15 and MEK 8 apparatus could transfer signals, without additional amplification, over distances of 170 up to 240 km depending on the wires type used and the weather conditions (rain and/or ice). (10, p.1) It was of the utmost importance to keep the tolerance of the involved line parameters within a few cm! Sometimes even crossings (rotations) had to be maintained somewhere in the cabling between two telegraph poles! (To retain optimal mutual symmetry)

The campaigns in western Europe

The border regions of eastern Germany were not extensively equipped with telephone facilities and subsequently the armed forces had to extend the lines from the telephone exchanges nearest to the Polish border themselves, though often with close cooperation of the German Reichspost. Both, army and air force built their own communication trunks, which, in some respect, can be seen as wasting manpower and material, though on the other hand it improved the flexibility of their communication systems. We have to consider that the Germans could descend upon Poland over a front stretching from the border of the former Czechoslovakia right up to the border of Lithuania which was, by then, occupied by the Russians. After the Molotov - Ribbentrop pact in Moscow on 25 th August 1939 both countries synchronized their future campaigns on Polish territory.

However, in August 1939 the Luftwaffe completed their own telephone system as part of the air force organisation (Ln = Luftnachrichtentruppe or air force signal corps). On 19 August 1939 a comprehensive signals manoeuvre took place (große Schaltübung or great telephone exchange exercise) in which all levels of command and their particular communication (line) networks were tested. (5, p. 8) However, we will not discuss the organisation of different levels of German command.

The Luftwaffe extended their line communication network with 4050 km telephone lines of all kinds. (750 km FD, 2000 km FFK and 1300 km sFK or special heavy field cable) At the end of August they had at their disposal a very comprehensive line communication network. (5, p. 9)

Communications over lines are, or can be, quite complex in nature bearing in mind that we have to consider that all sorts of message types had to be transferred. Orders often had to be sent out to many stations (divisions) at the same time and as this was, in effect, official documentation there was a need for it to be printed out. It was, as in all other major armies in the world, common practice to send these kinds of messages by means of teleprinters. For this paper we do not consider the operation of Feldhell (Feldfernschreiber or field Hell printer), which apparatus was widely employed by army services.

If we think of telephone line communications then we have to consider that telex or teletype messages were using the regular telephone line systems as well (as far as the military services were involved). The German army and air force both used so-called WT 40 interfaces (WT stands for "Wechselstrommehrfachtelegrafie" or multi channel AC current telegraphy) (in Britain known as "VFT" or voice-frequency telegraphy) which allowed for 6 - 12 different messages at the same time being handled on a single telephone (audio) channel (300-2000 Hz). Six channels could be utilized if a two wire system was used and twelve channels were available when a four wire system (2+2) was being deployed. It was even possible to increase the number of channels per line when "Phantom" circuits were being used.

The Germans still used, for the teleprinter service, the old fashioned word telegraphy operation. The military section which was concerned with telephone in the broad sense was still called "Telegrafentruppe" or telegraphy troops or corps, as well.

We have noticed that the Siemens MG 15 carrier telephony apparatus could transmit and receive 15 different telephone channels (we have to consider that the eight channel MEK 8 made by AEG was also widely used). When these carrier channels were entirely utilized for telex communications, there would have been 12 x 15 = 180 teleprinter channels available. However, in common usage, the lines were shared by both telephone and teleprinter operations (mixed service).

During tactical operations (campaigns) the front line troops were followed, as swiftly as possible, by the "Telegrafentruppe" (telephone troops) who had to install cable and/or air-line trunks. Let us take in to account that the campaign in Poland took only about three weeks and that according to Hoffmann (5, p. 15) the Ln-troops built, during this interval, 5000 km of sFK lines, 4800 km of FD (Telegrafenbau) air-lines and, on the other hand, repaired and reconstructed nearly 1500 km of Polish air-lines which were immediately incorporated in to the air force communication organisation. It is evident that they had put enormous effort (manpower and material) into completing this task within the space of three weeks. Comparable figures, for German army operations over this period, are not known to me.

According to General Praun the telephone facilities on Germany's western border during the first month of the war were in a rather premature state of development, and in no way sufficient to cope with the military requirements should France have eventually initiated an invasion of the "Siegfried line" (also called "Westwall"). (1, p. 106-118) Hoffmann noticed (from his wartime perspective) - how lucky it was that Hitler's plans to initiate a campaign in the west on 12/15 November 1939 or 17 January 1940 were not put into effect on those dates. (5, p. 35)

The theatre in western Europe 1940

It is evident that the German armed forces were preparing for a campaign in the west after they returned from the Polish theatre. During the heavy winter of 1939/40 the troops put all their efforts in to preparation for the "Tag X or Day X" (invasion of the Low Countries and France) which ultimately became code-named "Fall Gelb" or "Affair Yellow".

It was planned that the Luftwaffe would install, for every air force group, a separate "Drehkreuzachse" consisting of four or even up to eight core pair (2 or 3 mm Cu) - which could be used in either two or four wire circuits (2+2) and also in conjunction with carrier telephony and/or Phantom circuits. The future (tactical) lines which had to support the military operations could consist of open-wire construction and/or of FF cables (FFK or sFK). The "Achsen or line communication spills" were of the utmost importance for their advancing troops during operations and can be regarded as **the** "*funiculus or umbilical cord*" connecting with their commanding centres and organisations at the far end of the line.

Improvisation of all kinds became daily practice because the advancing troops were often moving too fast forward to be followed by the regular line construction troops. Almost without exception FFK cables were being utilized over distances of up to 120 km without additional amplification, whereas 80 km was already specified as beyond the limit. (5, p. 43)

In areas where the French troops had retreated and/or gave up fighting, the Germans worked hard to implement the line facilities of the French PTT (French equivalent of BPO) in to their own communication network. In most circumstances the French PTT showed considerable cooperation with the German military organisations. They continued doing so for the years to come and the French PTT even took an active role. But this seeming cooperation also had its "down side" for the Germans, because personnel of the French PTT had occasionally managed to build some subtle traps in to their own telephone system, which were being activated after D-Day and which were used to disturb or even block the German line transmissions. German specialists were then simply unable to trace the origin of the failures. (5, p. 268) According to Hoffmann the French long distance cable network, in 1939, consisted of about 6000 km. During the German occupation this network was, on behalf of the Germans, extended to a length of about 11,000 km. (5, p. 50)

Change in tactics

In the late 1930s reliable VHF and UHF valves were coming on the market. Although, magnetrons were widely available their operational reliability was not too good and most German companies sooner or later modified their transmitting equipment with valves, notwithstanding that this meant that sometimes lower frequencies had to be taken into consideration.

Beamed communication links were tested by many authorities in the world in the 1930's. It became possible to direct radio waves with small apertures creating beamed radio links. The German air force ministry (RLM) specified their technical requirements in close cooperation with Telefunken to get on hand a reliable radio link system (Richtfunkverkehr or abbreviated RV) which became known as the Michael apparatus (DMG 4.., 5..). It operated on a wavelength of 54 to 60 cm (500 - 555 MHz). The modified version which became available in 1939 could handle one speech channel and three "Telegrafie" or telex channels. The sets became quite popular and were widely employed in all main theatres in later war years. The Michael signal groups were equipped with very fine trucks, of which one carried the communication and auxiliary apparatus and the second truck carried a 30 m hydraulic telescopic mast, which was quite easy to erect (two of those 30 m masts were necessary if a station had to function as a relay post). From the tactical point of view this proved to be of life

saving importance as, for instance, near Stalingrad in the winter of 1942/43 after the Russians had pushed the German troops back. However, they could only use Michael links during darkness, because the Russians were hunting for any such communication facilities. The German air force ordered 3540 installations but until April 1945 only 2370 were delivered to them. (5, p. 332-) (11, p. 143-144, 169-170)

In 1941/42 the first "Rudolf" (DMG 3aG) apparatus, a more advanced equipment, became available which allowed nine telephony channels and one so-called "Dienstkanal" or service channel to be deployed. These nine channels were special carrier modulated by a FTF 10 or FTF 11 (FTF 12) interface, which generated a carrier signal of a bandwidth of 60 kHz. The transmission mode of the Rudolf equipment was FM modulation. By means of "WTZ" apparatus three telex signals could, at the same time, be transferred on each (telephony) channel. The Rudolf installation proved to be a powerful radio link tool in conjunction with line communications. Depending on the height of the individual antenna, distances of up to 200 km were technically (tactically) possible. Between 1942 and April 1945, 435 sets were supplied to the German air forces. (5, p. 333) (11, p. 170)

The Army purchased comparable equipment from the Lorenz Company, which apparatus became known as "Stuttgart I and II" (Fu G 03, ...) (1250 - 1400 MHz). From 1942/43 a few hundred of those 10 channel units were delivered to the Army. These installations were, more or less, comparable to the Michael apparatus as it was also equipped with a 30 m telescopic mast. (12, p. 118 - 120)

The introduction of "RV" in to military service did not necessarily mean that those installations were instantly and widely deployed in the armed forces signal service. It took quite some time before this medium became widely adopted.

However, the first use of RV occurred soon after the occupation of Denmark and Norway and was established between Sandefjord (100 km south of Oslo) and Hirthals 40 km South of Skagen (Denmark) over a distance of 170 km. The set used for this occasion was a Krabbe-Gerät and it was pushed to its technical limits. It was directly modulated by a MG 15 carrier telephone equipment which allowed the use of 15 or more telephone channels when telex was utilized. (5, p. 335)

Nevertheless, and despite its limitations, the Krabbe apparatus formed, after the German "Balkan campaign" (in spring 1941), the backbone of the telephone link from Crete via Athens, then Corfu to Monte Sardo at the very southern tip of the Italian peninsula. From here the signals were injected into the regular Italian telephone network and transferred to Berlin (or even up to Hitler's Command Centre "Wolfschanze" in East Prussia). The speech quality over this remarkably long distance was often better than a local Berlin call. These Krabbe installations were particularly modified by the Telefunken company for this task and it used wavelengths between 70 and 80 cm, which proved to be an optimal frequency band (12 W antenna power and amplitude modulation). The shortest distance that had to be bridged was 120 km and hardly any fading was observed during its operation. This service enabled thirteen long distance telephony channels and one "Dienstgespräch" or service channel. Each channel could handle, in conjunction with WT apparatus, up to 12 telex channels. This radio link was being operated almost without interference for over three years. Most failures were caused by the generator which caught fire, due to petrol evaporation in the intense heat. (13, p. 64-68)

As we will see later this extended signal path would become of strategic significance for German communications from, and to, North Africa as well.

North African theatre 1941 to 1942

We know that Rommel advanced very rapidly in Northern Africa, with this joint army and air force operations, after he had landed in Tripoli in spring 1941. As usual the signal troops followed Rommel's successful campaign in Libya as rapidly as possible. The line facilities in North Africa were, compared with the European continent, extremely underdeveloped and in a sense rather catastrophic and hence during the early days of their campaign the "Afrikakorps" had no other choice than to rely mainly on wireless communications. Step by step more line facilities became available and non mobile services were connected to the telephone system. These air-lines consisted mainly of 2 or, sometimes, 4 wires (Cu 2 or 3 mm). According to Hoffmann the British air-lines, which were left behind after their retreat in the direction of the Egyptian border, were of much better quality than those of the Italians! (5, p. 242)

Teleprinter (Fernschreib) communications were of very great importance for the German armed forces because orders and directions were printed out and could also be filed. To improve the understanding of the matters relating to the telex service (Fernschreibtruppe) let me give a brief explanation. The telex service troops can be divided into both regular and the so-called "G-Schreibtrupps" or top secret teleprinter service. Both machines but were in a sense of different types and the regular line "G-Schreiber" (SFM 52 c or d) was equipped with an integrated (built in) coding-decoding facility which allowed online coding and decoding of messages. We are not here considering the wireless signals of the secret telex apparatus SZ 40 or SZ 42 (Lorenz). This signal operation (service) was called "Sägefisch I, II,..." or Fish by the British and its codes were later cracked by the efforts of Colossus in Bletchley Park. Interestingly, breaking these message codes took - despite Colossus - considerably more time then breaking the regular Enigma messages.

Top secret telex had to be handled with the very greatest care and had to be guarded for 24 hours a day and very special precautions had to be taken to see that those machines were kept out of the hands of the enemy. Due to these requirements, the first troops arriving in North Africa were not sufficiently supplied with G-Schreibers.

Improvisation often became daily practise and one had to work with the equipment available. Hoffmann mentioned in his book the following, rather illustrative, story.

Nonetheless, command orders had to be communicated and kept secret which posed a problem if no secret teleprinter apparatus was available. Some operators used a definitely prohibited transmission mode, - they passed on a prepared punch tapes, in reverse, through the punch tape reader! Under military law this was a criminal offence but, what other choice would they have had under those circumstances (and who the hell would tap those lines in the African desert anyway?). (5, p. 237-...)

However, as time went on communications became more and more organized. The telex service could use the Italian cable between Benghazi and Syracuse on Sicily and could also send their messages via a UHF radio link (RV), the first station on the African side being positioned in Derna with an additional station at El Dhaba later on (we neglect for the moment the Sägefisch" short wave wireless service).

Previously we have learned about the Krabbe installation on Crete and this UHF link was later also extended to a station near Derna on the African continent (air distance Derna Crete about 350 km). A tropospheric phenomenon ensured its solid operation. This phenomenon was caused by hot air layers over the Mediterranean at a height of 1000 up to 4000 m at a temperature of 50 to 60 ° C during daytime (temperature inversion). (5, p. 391)

On the nights of the 8/9 or 12/13 July 1942 SAS troops raided some tents in El Dhaba but just failed to destroy the one which would have resulted in knocking out the only remaining telephone link to the European continent. Hoffmann is not certain whether or not this SAS raid was actually targeting this important communication site. (5, p. 391)

We have noticed that this radio link was often the only "life saving" telephone facility to Europe and can be regarded as a virtual umbilical cord. The American General Omar Bradley expressed it in slightly different terms after the invasion in 1944: - *Our rapid drive across France was dependant on a shoe string. That shoe string was a radio link.* (5, p. 436)

From Russia up to the bitter end

The German invasion of Russia on 22 June 1941 initiated the most heavy and large scale fighting the world had ever seen. The quantities of man power and material involved, even for today, were enormous and can be regarded, in my opinion, as the "longest Battle in History". The invasion on D-Day was, in respect to man power and material, only a medium sized operation! On the other hand the German campaign in eastern Europe was a war, in most respect, of quantities rather than quality. I regret that, still today, most western historians seem to neglect the implications of this German involvement against Russia. It tied up millions of men, which (luckily for us) severely hampered the German war efforts in other theatres.

The first very important experience the German armed forces encountered in Russia was the emptiness of the country. In western Europe distances are counted in hundreds of km, whereas in Russia you have to count in thousands of kilometres. The implication on communications in general is evident especially after the Russian "Partisan" resistance became a very dangerous threat in the German army's rear. The Russian resistance aimed, in the first place, to disrupt German lines of communication and transport because, of course, the Partisans were not strong enough to fight direct battles against German armies. Nevertheless, they were of considerable support to Russian military operations.

The army was regularly equipped with long and medium wave transmitters (30 WS, 80 WS and 100 WS, 100 kHz - 3000 kHz) which allowed wireless communications up to 250 km. Short wave was unfavourable because most counter stations were often in the so called "skip distance" which meant that radio waves could not be received regularly. (1, p. 138, 273) This phenomenon stressed the need for installing telephone facilities which, especially in the early

days of the invasion in Russia, had mainly to rely on combinations of various cables and air-lines.

Consider the problems faced by signal troops who had to follow the very fast movements of Guderian's panzer divisions, which sometimes advanced a hundred or more kilometres a day!

The German Army and Luftwaffe both built their own telephone lines boarding either side of the roads (as far as one may express this word for most Russian tracks). The Luftwaffe followed the left hand side and the Army the right hand side of the road (always in respect to direction of the advance). This proved to be necessary because the rotation of the lines of the "Drehkreuzachsen" were contrary to each other (left and right line spin). (5, p. 83)

The High Command of the 2 Panzerarmee" (Guderian's tank army) noted that their achievements in line constructions between 22 June and 30 November 1941 were, according to Praun: (1, p. 270-273)

- That it was the III/F.N.R. 40 (III/signal Regiment 40) who built and/or reconstructed a total length of 7804 km telephone line (FFK and FD) (equal to the distance Berlin - Peking)

According to Hoffmann (Luftwaffe) (5, p.117- 118)

- Ln-Regiment 22 construct an average of 40 km/day whereas it normally did 20 to 24 km/day.

As the war years advanced the density of available lines improved. However, the huge distances involved and the disruption caused by the Partisans (who continuously worked to destroy German line communication network facilities) forced the Germans to rely more and more on radio links. In fact this was a logical solution as it reduced both man power and the quantities of valuable materials used as, for instance, copper (Cu) which was regarded as a strategical material.

According to an American calculation concerning the impact of man power and material on regular line communication facilities versus radio links (5, p. 329): -

- To build 160 km (100 mile) of four wire air-line (2+2), 94 BRT ship loads of material was needed and to install this line would take 10 days and 2000 men.

Whereas

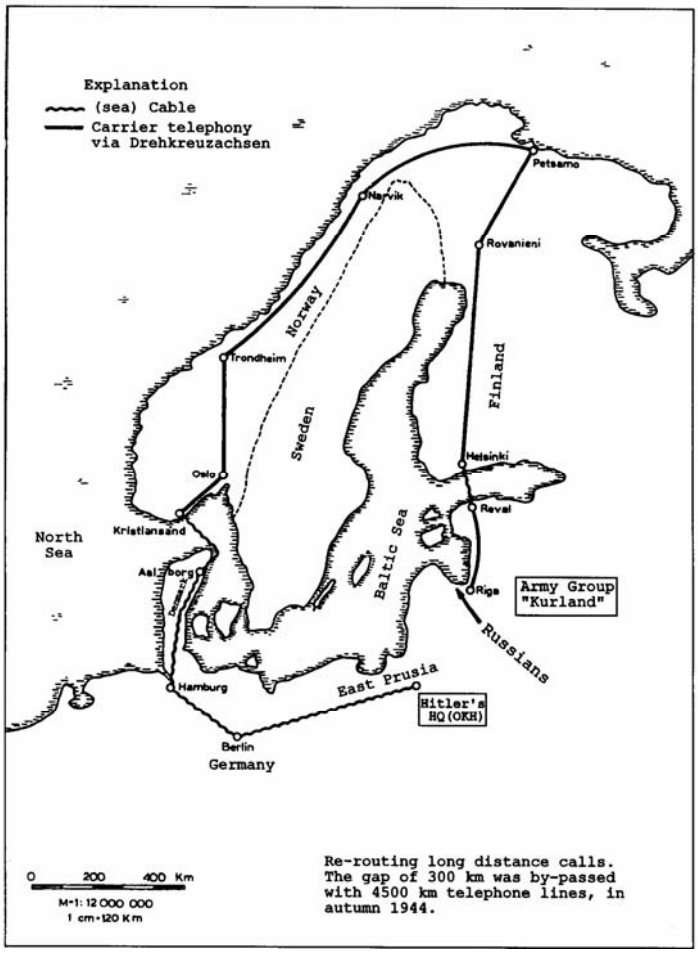
- A radio link bridging this distance could be built within 10 hours using only 44 men.

If we consider distances of the order of 1600 km (1000 mile) as were not uncommon in Russia, then the saving would amount to about 20,000 men, which is more or less equivalent to one German army division!

As an illustration of how capable the German line organisation was, let me recount an anecdote told to me, a few years ago, by the late Karl Otto Hoffmann himself.

In the summer of 1943 his signal regiment (Ln-Betr.-Abt. z.b.V. 10) was stationed in Luga in the northern section of the eastern front. On a particular evening his commanding officer Major Zimmermann visited the quarters of the signal group and, after a while, the C.O. said that he had to go back to his own quarters, because he would like to write a letter to his wife. They looked at him with a smile and asked him: - "who the hell, as a member of a signal group, would write letters?". He looked at them and didn't understood what they meant and said - "there is no other way to get in touch with my wife?". They grinned and one said: - "yes there is ... a telephone call!". He still didn't believe what he just heard and asked how, and is this legal (not officially, but tolerated during low traffic hours)? It was arranged that the next evening provision would be made to switch lines for a so-called "Konferenz-Schaltung" or conference link connection between him, his wife living in Gremsmühlen-Malente (western part of Germany, about 1700 km away from Luga) and his son who was stationed in Crete! How many km of cable and/or line and repeater stations were involved? The signal path over occupied Russian territory was managed by the Luftwaffe organisation (so-called LVs), the line section over German territory up to southern Italy was mainly handled by the regular telephone authorities and the route to Crete was again managed by the Luftwaffe signal service. (see also, 5, p. 95)

Probably the most striking example of long distance by-passing or rerouting signals took place in the autumn of 1944.



If we consider the map on the previous page, then we can clearly understand what happened. The Russians broke through the German front line and reached the coast of the Baltic Sea and cut off all lines between East Prussia and the so-called "Kurlandfront" just south of Riga. To ensure un-intercepted communications between Hitler's HQ Wolfschanze near Rastenburg and the isolated army group "Kurland" the signal path went from:

- Riga to Reval in Estonia via Drehkreuzachse
- By sea-cable to Helsinki
- Then again transferred by carrier signals via a "Drehkreuzachse" to Kristiansland
- Via sea-cable to Denmark and then over regular cables to the army HQ

To fill the communication gap of 300 km, line facilities of up to 4500 km had to be switched. The speech quality was a bit "meagre", but teleprinters worked without problems. (1, p. 235)

During WW II German line facilities certainly passed many hundred million messages and even in the days of Germany's "Apocalypse", the Germany army High Command Centre (HQ) "Zeppelin" in Zossen, could still handle, in January 1945, a **daily** average of:

- 20,000 "Fernschreiben" or telex messages
- 120,000 long distance calls

Zeppelin was **the** Army Command "nerve centre" near Berlin. It was connected by fixed (permanent) lines (which were always available) with all war theatres in Europe up to the bitter end. (1, p. 240) After the war the Russians took over control of this huge underground bunker complex and incorporated it in to their own military organisation.

The armed forces managed to overcome most bottlenecks, despite the devastating bombardments of German territory and its resources. In a sense they could still rely on their own RV and/or "Drehkreuzachsen". And the Luftwaffe still possessed 75 to 80 % of the long distance line facilities of the Reichspost. (5, p.307)

The Luftwaffe deployed and maintained about 50,000 km RV links at those places in Europe and north Africa which were of utmost importance for their signal organisations. (5, p. 436) Figures concerning army RV links are not known to me, but I would be very surprised if they amounted to less than 20,000 km.

Some Backgrounds and conclusion

In discussing some aspects of German armed forces line communications I have ignored the existence of Navy line communications because, in my opinion, these were outside the context of this paper as the German navy did not have any real system of their own generally using the regular (civilian) phone service.

We have looked at some aspects of German military line communications. If we look back to the days of the so-called "Great War" (1914-18) then it is apparent that the German army could look back on a long history of traditional line communications. It is also evident that

they continued working in this field. We can also see from the historical background that the army signal organisation, though thorough, was based on a rather conventional organisation.

Due to the political changes of the 1930s and the great improvements in "avionics" in general, the establishment of a new air force was particularly appealing to young people with its aura of adventure and daring. Many young and intelligent men were selected for the creation of a powerful new "Luftwaffe".

Goering was a highly decorated war hero of WW I and he had served in "Richthofen's" group. His political involvement in the Nazi hierarchy put him in a very special position in which he was able to control large parts of the German industry and their resources. He established the so-called "Vierjahresplan" an organisation which aimed to enhance Germany's industrial "autarchy" (self-sufficiency). The purpose of this organisation was to force the industry to minimize imports of raw materials of all kind. Due to his enormous influence in the German industrial complex he was able to select and sequester most supplies necessary for the built-up of his new air force. With this latter background in mind we may say that the German Luftwaffe was the best equipped of all armed services and may be regarded as an elite troop, followed by the Navy and in third place came the regular army ("Heer")!

Consequently, the Luftwaffe possessed the best communication facilities (resources), in respect of both quality and quantity. Between army and air force there sometimes existed quite some animosity, due to the army's tendency to boast of their heavy weaponry and their traditional role as **the** armed service. (see also, 1, p. 229, 233) Both attitudes are clearly reflected in the two books which served as my main references. The best of these two is Karl Otto Hoffmann's book the "Geschichte der Luftnachrichtentruppe" or the history of the air force signal troops. This book (one of a series of three) reflect a period of about twenty five years of preparation. Hoffmann served as an officer in the German air force line communication service from the mid 1930s through to 1970 with a break in the post war period when Germany had no armed services.

General Praun's (successor of General Fellgiebel, see hereafter) book concerns more his own memory recollection and in many respects does not entirely reflect **the** history of army communications. Nonetheless, he became, in the autumn of 1944, the C in C of all German army communications and could take an overview from a different perspective.

Hitler's last gamble was probably the "Battle of the Bulge" which was started on 16 December 1944 and its initiation proved to be a complete surprise for the Allied Forces in western Europe. How could this happen, despite all the efforts of Allied intelligence and the apparent successes of Bletchley Park? The explanation is: - Hitler's directive to abandon all wireless communications concerning anything that could be linked with this future military operation. Consequently, military communications had entirely to rely on line connections. (14, p. 35-44)

In conclusion, we have considered some aspects of German line communications and I think we can say that in the early war years these were "state of the art", particularly in respect of the extent of their networks. Every conversation over line, what ever its nature, was effectually a hidden message, one which, in most cases, could not been intercepted by Allied "Y-services" at all. (Some RV links in the Mediterranean theatre were occasionally

intercepted (from Malta) and also some telephone lines were tapped where they passed over Swedish territory).

There is little doubt that military line communications proved to be of "strategic" significance for the German armed forces during World War Two.

However, a severe disadvantage of good communications is that the German High Command, especially Hitler, was (due to those extensive facilities) able to intervene at any time and in nearly all circumstances. In the 1800's Moltke has once mentioned: - *that a "Feldherr" or field general has most to fear whilst there is still a direct telegraph line to the rear*!

Although, not discussed in this paper, the assassination attempt on Hitler on 20 July 1944 and the coup d'état of a group of generals failed in part due to the complexity of German military communications. The hardware and the way the lines were organized and connected (existence of two independent communication networks, see also 5, p. 60) caused the reiteration of orders over different signal routs towards those who were in charge (had to know about it or were concerned). General Fellgiebel (C in C of army communications) could not foresee that his instructions and orders to block all communications with Hitler's HQ were automatically sent, via a different (by-pass) route, to the centre that was supposed to be switched off! This is why the Gestapo knew, within a few hours, who was to blame for it. (see also, 1, p. 222)

Reflections

Britain's finest hours, in the field of detection and unravelling of communications (kept for so many years as a top secret) were only made possible because of the extensive use of wireless communication by the German armed forces during WW II. Without this, Britain would certainly have had a rather more difficult job to beat the German military forces in this war! We only have to think of the implication of Ultra and HF/DF, which could hardly have supported the Allied war efforts without the availability of German wireless signals. We have previously learned that the German armed forces relied heavily, in many respects, on line communications. As long as the front wasn't moving line telephony was extensively utilized. Only remote stations at the far end of the communication line, were compulsory relying on regular wireless communications. On the other hand, what would have happened if the Germans had not used wireless linked communications in the way they did? However, this hypothesis is only of academic significance, because the Germans had, in many respects, - despite their extensive line facilities - no other choice then to use wireless for their tactical communications.

Acknowledgement

I have to thank all those who have supported me with information. As I have mentioned in the synopsis of this paper, the general interest in line communications is rather limited. And as a consequence it has proved to be difficult to get access to relevant additional sources. In the first place I have to thank Günter Hütter for his generous support. Thanks to his very

comprehensive archives I could find much relevant information, whose content was far beyond what I could have expected to find when I started the preparation of this paper. Although, my interest in this subject has continued for over twenty two years, the realisation of this publication could never have come about without the support of the late Karl Otto Hoffmann and of, Peter Brinkenberg, John Bullen, Ralph Erskine, Gertjan Huysman, Wim Jung, Helmut Liebich, Hans Richter, Rudolf Ritter and Werner Thote.

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Abbreviations

AF Audio frequency
BPO British Post Office
BRT Bruto register tonnage (deadweight capacity/tonnage)
C in C Commander in Chief
C.O. Commanding Officer
Cu Copper
DM Dieselhorst-Martin a special type of telephone cable
DMG Decimeter radio link apparatus (**D**ezi**m**eter**g**erät)
DRP German Post Office (**D**eutsche **R**eichs**p**ost)
FD Permanent air-lines
FFK Field cable (**F**eld**f**ern**k**abel) (often similar with "Spiral four")
FM Frequency modulation
FTF Special carrier telephony apparatus
Fu G Wireless apparatus (**F**unk**g**erät) sometimes written as FuG
G- Secret-... (**G**eheim- ...)
HQ Head Quarters
ISDN Integrated Services Digital Network
Ln Luftwaffe signal Corps or German air force signal organisation
LV German air force exchange station (**L**uftwaffe**v**ermittlung)
MEK AEG multi channel carrier telephony apparatus (**M**ehrfach-**E**inzel**k**analgerät)
MG Siemens multi channel carrier telephony apparatus
PCM Pulse Coded Modulation
PO Post Office
PTT Post Telegraph Telephone
RLM German air ministry (**R**eichs**l**uftfahrt**m**inisterium)
RV Radio link (**R**ichtfunk**v**erkehr)
SAS Special Air Services
sFK Heavy multi channel field cable (**s**chweres **F**ührungsfern**k**abel)
SZ Teleprinter coding/decoding device (**S**chlüssel**z**usatzgerät)
TF Carrier apparatus (**T**räger**f**requenzgerät)
UHF Ultra high frequency
VHF Very high frequency
VFT Voice-frequency telegraphy apparatus
WT Similar to British VFT apparatus (**W**echselstrommehrfach**t**elegrafie)
WTZ Special version of WT apparatus

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