

Institute's History



Figure 1-1: Max Dieckmann, picture, oil on wood. Painter: O. Pippel, 1935, Location: Institute's foyer.

Introduction

The present "Microwaves and Radar Institute" of the DLR was founded in 1937 as the "Flugfunk-Forschungsinstitut Oberpfaffenhofen – FFO" (Aircraft Radio Research Institute Oberpfaffenhofen) under the leadership of Prof. Max Dieckmann. This is the origin of the DLR research site in Oberpfaffenhofen near Munich.

However, the Institute's history can be traced back to 1908 when Dr. Max Dieckmann founded his private "Drahtlostelegraphische und Luftelektrische Versuchsanstalt Gräfelfing – DVG" (Wireless Telegraphic and Air Electricity Test Station Gräfelfing) located in Gräfelfing near Munich, 13 km from Oberpfaffenhofen. The goals of the DVG were the

application of electromagnetic waves for communication, navigation, and radio location as well as the research of electric processes in the atmosphere. Using modern terminology, the work encompassed microwave technology, radio measurement techniques (radar), jamming, and determination of aircraft signatures by model measurements. Particularly in the early years, antenna development was predominant.

Remembering that Heinrich Hertz had discovered electromagnetic waves twenty years beforehand, the DVG Institute seems to be the first microwave laboratory world wide dedicated to the research of microwave techniques and applications.

The Radio Telegraphic and Air Electricity Test Station Gräfelfing (DVG)

100 years ago, on October 14, 1908, Max Dieckmann, Assistant Professor at the Technical University Munich, hired a meadow with a small cabin in Gräfelfing near Munich and founded the DVG. The purpose was to develop the then very new and exciting area of wireless techniques, to investigate the effects of natural electrostatic phenomena and to use that facility as an experimental station for his students.

One of the very early developments was the "safe" spark gap transmitter for operation on board Zeppelin airships, which were then filled with highly inflammable hydrogen gas. Together with the former Telefunken Company (now EADS Defence), Dieckmann succeeded in constructing a hermetically sealed cabinet containing the spark gap

transmitter and an antenna which was adequately isolated from the gondola environment. A very successful field trial was conducted to demonstrate the usefulness of airborne wireless radio stations in 1911/12, when the airships "Victoria Luise" and "Hansa" exchanged telegrams over distances of 250 km (see Figures 1-2 and 1-3). The antenna was the first developed in Gräfelfing. As a result of this success, almost all Zeppelin airships were equipped with such radio stations that communicated with the first ground station near Frankfurt.

This was indeed the birth of airborne radio communication. Further developments included the development of simple methods for locating the position of an airship by comparing signal strengths received from different ground stations. Also, the DVG developed a special gas-tight skin which had a certain degree of electrical conductivity. This feature guaranteed that static electricity would not accumulate and give rise to sparks.

In 1914 the DVG also developed a first frame direction finder and used it for ship navigation on the nearby lake Ammersee. During the First World War, such instruments were installed on airships for navigation via ground based transmitters (see Figure 1-4).

During the First World War, the research in Gräfelfing decreased. Prof. Dieckmann served in the Imperial German Army as a director of the Air Force Wireless Research Laboratory at Döberitz near Berlin. During this time, he invented and developed an apparatus for the detection of phone cables (1914) and a system whereby an observer in a basket lifted by a balloon was connected to a ground station by a 1000 m long wire (see Figure 1-5). Later this was performed with an airship flying above the clouds and, therefore, invisible from the ground. He also developed a first instrument for radio transmission of images (facsimile). The necessity of such techniques came



Figure 1-2: Dr. Max Dieckmann and the wireless radio station on-board the airship "Victoria Luise", 1912.

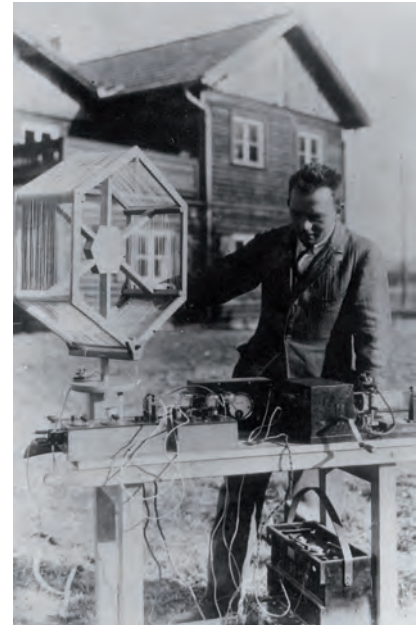


Figure 1-4: Experiment equipment with a DVG frame direction finder.

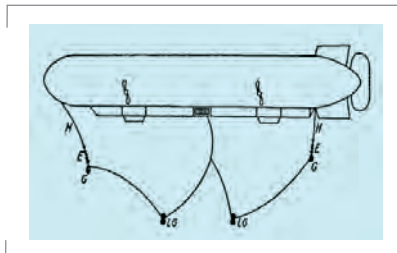


Figure 1-3: Zeppelin airship with an early wire antenna.

from the airborne reconnaissance units for supporting the artillery. Detected enemy positions were conveyed more swiftly and accurately by the transmission of hand sketches and annotated map sections.

These inventions proved to be of great importance for the Institute when the image transmission technique was further developed in the years 1922 to 1929. During 1926, first attempts were

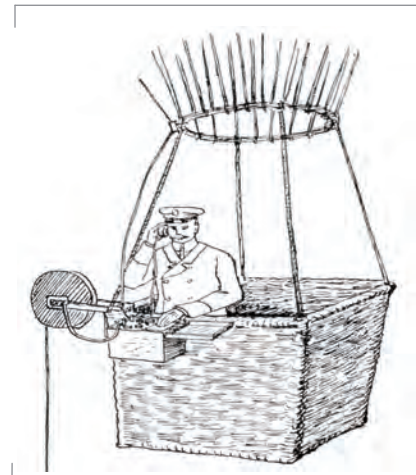


Figure 1-5: Observer in a balloon basket with a communication link to the ground.

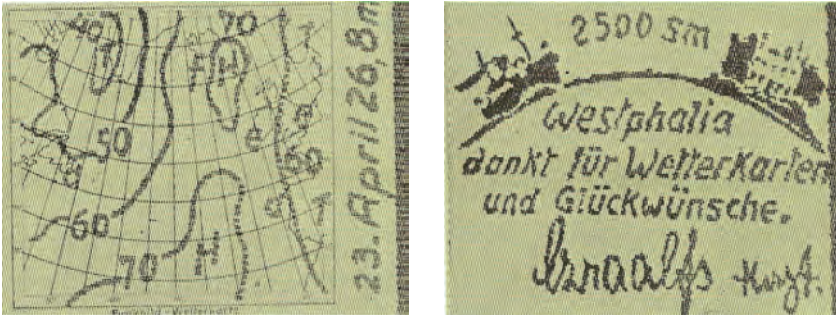


Figure 1-6: Radio weather map sent in 1926 from Radio Norddeich to the “Westphalia” over 4600 km via the DVG radio technique with a thank-you and congratulations message from the ship’s captain.

made to operationally transmit weather maps to the public at large via the medium wave broadcast transmitter in Munich, and via the German coastal radio station in Norddeich to ships on intercontinental routes. Figure 1-6 shows an example of such a weather map of the North Atlantic sent to the liner “Westphalia” over a distance of approx. 4600 km. A block circuit diagram in Figure 1-7 shows the principle of the system. The originals were scanned on a cylinder with a two-bit resolution. Several different printing techniques had been investigated for the receiver, e.g. an ink-jet process, also in colour (see Figure 1-8), or a hot stylus process to melt and transfer the colour from a colour carrier sheet.

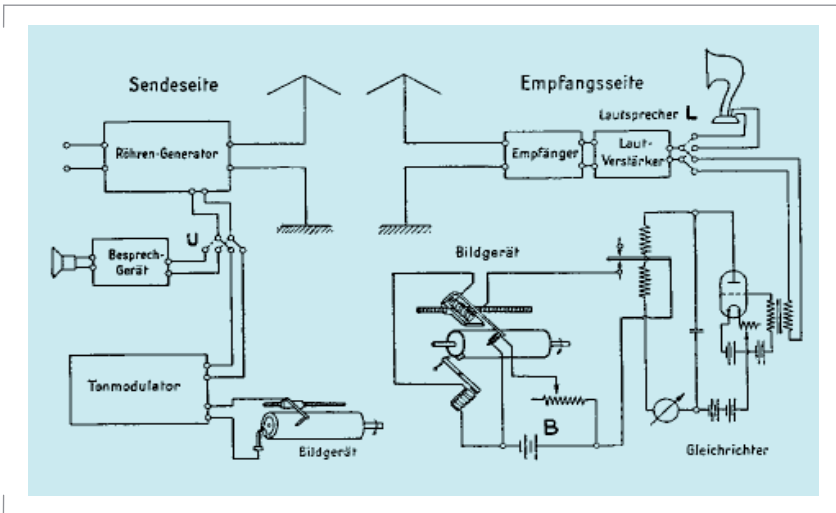


Figure 1-7: Circuit diagram of the DVG image transmission system used for weather map transmission in 1926 to “Westphalia”.

The other problem intensively investigated was the localization of aircraft, either from the ground or from the aircraft itself. The growth of civil air transportation services imposed an urgent need for a reliable system for localizing aircraft and thereby maintaining air traffic security.

Several patents were awarded to the Gräfelfing team for the development of specialized airborne receivers to measure the angular bearings of ground transmitters, either to get a reference for its own position, or to estimate the correct air traffic route. Figure 1-9 shows such an instrument from around 1935, which used a fixed loop antenna in conjunction with the main communication wire antenna to derive the angular deviation from a ground transmitter relative to the aircraft axis. At the left in the figure, the cockpit instrumentation can be seen which indicated this deviation. Later on, receivers of this type were installed in fighter aircraft of the newly established German Air Force.



Figure 1-8: Image of the DVG building at Gräfelfing, painted by Max Dieckmann and transmitted with the DVG image radio transmission technique.

In the year 1928, an additional test site on the western shore of Lake Ammersee near the village of Riederau was established. Experiments on precise

direction finding devices require well defined natural surroundings for proper estimation of system performance and propagation parameters. The water surface of the lake was therefore an ideal choice for such a test site. At Riederau, first experiments for remote radio controlled vehicles were carried out. These experiments generated widespread public interest, as can be seen in a newspaper clip from the "Gelsenkirchener Allgemeine Zeitung" dated September 24, 1928 (Figure 1-10).

The Airborne Radio Research Institute Oberpfaffenhofen (FFO)

After 1935, the German Air Ministry identified that the German research facilities in the field of RF techniques were insufficient for the applications to communications, navigation and radio detecting systems required by the German Air Force. Therefore, Prof. Dieckmann was asked by the Air Force to intensify his experimental work to establish a new institute for airborne radio research. Prof. Dieckmann accepted this task and looked for a location somewhere between Gräfelfing and Riederau. He found a place large enough in the immediate neighbourhood of the Dornier airfield near the village Oberpfaffenhofen. This newly established facility bore the name "Flugfunk-Forschungsinstitut Oberpfaffenhofen (FFO)" and activities formally commenced in the year 1937.

The key personnel came from the Institute in Gräfelfing. The FFO started with a staff of 115 members: 17 executive engineers and autonomous scientists, 35 engineers, technicians and scientific assistants, 15 other employees, 34 mechanics and craftsmen, as well as

17 labourers and assistants. They were divided into the following branches:

- General sciences (8): General scientific and theoretical work, reports, patents, library, scientific secretariat
- Research branch A (14): Direction finder in all wavelengths, wave propagation and multipath effects, short time measurement techniques, ultra short waves (today VHF and UHF), tubes (valves) and tube systems
- Research branch B (14): Self-excitation, energy lines, on board equipment
- Mechanical workshop and operations (38): Construction, precision and coarse mechanics, assembling, house keeping
- Flight department (13): Air traffic for research, travelling, training, aircraft maintenance and repair



Figure 1-9: Specialised airborne receiver for direction and route finding.

Figure 1-10: Experiments for remote radio controlled vehicles.





Figure 1-11: Building of the Flugfunk-Forschungsinstitut Oberpfaffenhofen at the beginning in 1937.

the next three chapters will be dedicated to the radar research and development in FFO and DVG.

The Development of Pulsed Airborne Radar for Height Determination

A very early development of a radar system was undertaken at the beginning of 1935 and continued in the following years at the DVG. The aim was to determine the real height of an aircraft above ground by means of an electrical echo sounder (altimeter). At this time, the ionospheric echo sounding method by transmitting short RF pulses in the zenith direction was already known. This method had been developed by Breit and Tuve in the US in the late twenties and was used later at different sites in Europe to analyse ionospheric phenomena, which were important in order to predict commercial intercontinental short-wave links.

To our knowledge, it was at the DVG that this sounding principle was applied for the first time by measuring the delay of RF echoes reflected from the ground from flying aircraft, in order to measure the precise height over ground. This apparatus used a wavelength of $\lambda = 7$ m (equivalent to a carrier frequency $f = 42$ MHz) and a transmitter pulse length of less than $0.5 \mu\text{s}$. Some rare pictures on glass-plates of the apparatuses survived the war and were found in the cellar of the Institute some years ago. A selection is shown in the next figures. These very early experiments with an airborne radar had been undertaken in the second half of the year 1935 using a Junkers W-34 aircraft of the DVL organisation (Figure 1-13) which was stationed on the SchleiBheim airfield, some 20 kilometres north of Munich. A sketch of the aerials fitted to this aircraft is shown in Figure 1-14.

For displaying the results at high resolution and distances of at least 10 km, the developers initially used a Cathode Ray Tube (CRT) of an early Telefunken TV set, exhibiting a screen

At first, the FFO consisted of a laboratory building and a hangar. The building is still being used (see Figure 1-11).

The enthusiastic beginning was, however, marred by a tragic accident when a Ju52 aircraft with six engineers and pilots on board crashed near Kassel during the night of November 4, 1937 while on its way back to Oberpfaffenhofen.

In the following years, research was mainly concentrated on developing the emerging microwave technology; and antenna research and development was a central topic. Figure 1-12 shows an engineer during experiments with wave guide and Fresnel lens antennas.

Especially radar problems required an ever-growing part of human and technical resources. Direction finding techniques for different purposes had been developed during the war and in the twenties and early thirties, due to the worldwide progress in the development of innovative electronic devices, like high-power magnetrons, detector devices and the forgotten invention of Hülsmeyer for detecting objects via the reflection of electromagnetic waves gained increasing importance. Both the DVG and the FFO took up that topic, which is now called radar, as a central research activity. Because radar research has been a key topic since the thirties,



Figure 1-12: An engineer during experiments with wave guide and Fresnel lens antennas.



Figure 1-13: Junkers W-34 aircraft carrying the DVG experimental short-wave height measuring radar at the SchleiBheim airfield near Munich, autumn 1935.

diameter of about 20 cm (huge at the time) with magnetic electron beam deflection (see Figure 1-15).

The circuit diagram of the first developmental stage is shown in Figure 1-18.

The engineers tried to expand the distance co-ordinate (to obtain a more precise reading) into a zigzag line. Experiments showed this not to be sufficient, so that in a later stage (during 1936) a circular electron beam trace was written onto the CRT screen with a dark-point triggered by the ground echo. This gave better readings with a much clearer picture.

A photograph of such a CRT display is depicted in Figure 1-16, which shows the case of an aircraft flying at a height of 2500 m. Later on, an advanced CRT construction using electrostatic deflection made the deflection amplifier more sensitive, requiring a much lower RF output power. The installation of the radar transmitter and the CRT deflection amplifier during a measurement campaign in 1935/36 inside the Junkers W-34 aircraft can be seen in Figure 1-17. The transmitter delivered a peak power of about 200 W at a pulse repetition rate (PRF) of 15 kHz.

The observations described in the test report showed that the influence of the reflecting surface had a strong impact on the precision of the reading. Especially during the very early experiments, the strong absorption of RF waves of forested areas caused difficulties because of insufficient echo strength and strong signal fluctuations. Optimal results were observed over water. Furthermore, there were interesting observations regarding the detection of coasts or lake shores, because of the wide antenna beams. The observer could detect the approaching coastal reflections from the off-nadir angles on the screen and could relatively accurately determine the moment of a coastal approach.

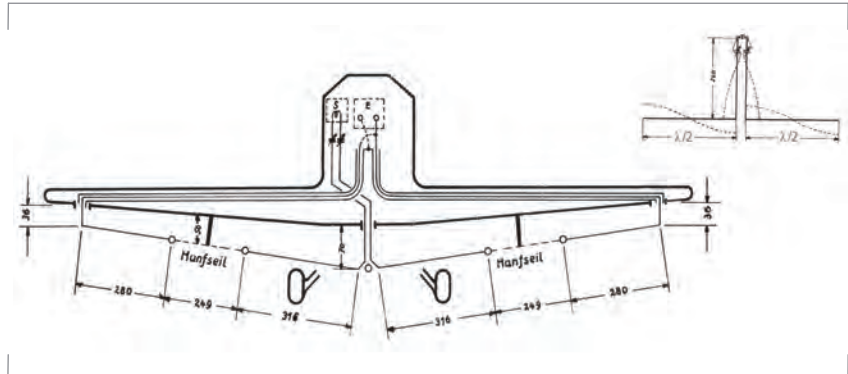


Figure 1-14: Sketch of short-wave antennas developed for the first experiments with the electrical echo sounder of the DVG mounted on a Junkers W 34 aircraft.

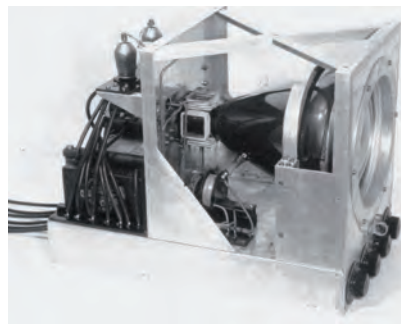


Figure 1-15: Monitor module, the first developmental stage of the DVG echo sounder; CRT diameter 20 cm with magnetic beam deflection from an early television set.

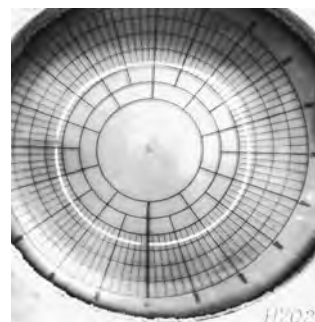


Figure 1-16: Echo sounder CRT display during a flight test at a height of 2500 m above ground. The deviation from a circle shows the problems of non-ideal magnetic deflection coils and other stray fields.

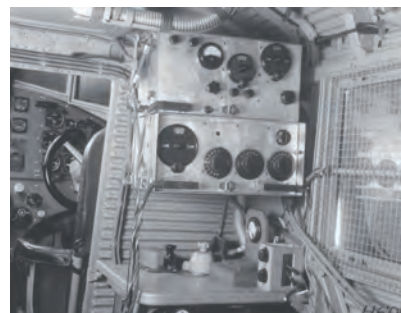


Figure 1-17: Installation of two echo sounder modules. Above the pulse transmitter, $\lambda = 7$ m (42.9 MHz) and the CRT deflection amplifier and PRF generator, fixed by elastic ropes.