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RADIO AND RADAR EQUIPMENT IN THE LUFTWAFFE - V.

I.F.F.

1. This report is the fifth of the series dealing with radio and radar equipment in the Luftwaffe. As in the case of the previous four reports (A.D.I.(K) 343, 357, 362 and 363/1945), it is based on interrogation of General Nachrichtenführer MARTINI, Director General of G.A.F. Signals, and some members of his staff, and has been supported by a number of relevant documents of recent date which were in the possession of the General's Chief of Staff.

2. For convenience in reading, the report is divided into three main sections covering the following applications of I.F.F.

- A - Flak.
- B - Early Warning Radar.
- C - Air-to-Air Recognition.

GERMAN VIEWS ON THE IMPORTANCE OF I.F.F.

3. Before the outbreak of war the practical application of radar was mainly concentrated upon its use as an aid to Flak, and the Germans did not realise the importance of an early warning service until after hostilities had begun. In consequence the need for the identification of friendly aircraft picked up by radar sets arose initially mainly in conjunction with Flak requirements.

4. Owing possibly to the fact that the first solution to the Flak problem was not as successful as that achieved in connection with early-warning radar, while at the time great importance was attached to Flak as a defensive weapon, much effort was devoted in the first few years to producing a suitable identification system for that arm.

5. By 1944, the American bomber force was able to bomb Berlin by daylight in clear weather with insignificant losses by Flak, despite the application of various radar and optical aids. As a result, Flak had fallen into disrepute as to defensive weapon.

6. This opinion of the ineffectiveness of Flak was very pronounced among the members of the Signals Staff of the G.A.F. and it is hoped to give their reasons for this view in a later report in this series on Ground Radar. Flak was regarded by them as an out of date weapon and for this reason as well as on account of the inherent difficulties of the problem, practically no effort was made to provide a means of identification of friendly aircraft for Flak purposes during the later stages of the war.

7. On the other hand the position of early warning radar was exactly the reverse and as early warning became vital so the G.A.F. attached ever greater importance to I.F.F. for early Warning radars, particularly in connection with bad weather and night raids involving feints and spoof sorties. It was considered essential to obtain a clear picture of the tracks of Allied raiding aircraft and to avoid any confusion with German fighter aircraft which also flew in group. The latest endeavour in this field went so far as to provide separate identification for different G.A.F. night fighter units in order to assist ground control still further.

8. Increasing attention was also being paid to air-to-air recognition between German aircraft but this, though considered desirable, was not thought to be nearly so important as the essential requirement that friendly aircraft should be recognisable to the early warning service In order that a true picture of the progress of Allied bomber attacks could be obtained and fighter aircraft vectored to the attack by ground control.

#### A - I.F.F. FOR FLAK

9. At the beginning of 1939 it was intended to equip all Flak sites with a radar fire control apparatus then being developed by the firm of Lorenz. The Lorenz apparatus proved unsatisfactory and in the course of 1939 the Würzburg, produced by Telefunken, was adopted for Flak fire control.

10. The need for the recognition of friendly aircraft for Flak purposes had been apparent to the Germans and an I.F.F. set for use with the Würzburg was produced, and was available at the outbreak of war. It was known as the Zwilling and was given the designation FuGe 25.

11. The 50 cm. Würzburg transmission received by the FuGe 25 caused the FuGe 25 transmitter to broadcast an audible morse signal on the same frequency, which could then be heard by the Würzburg operator in his headphones. As this was not a re-transmission of the Würzburg radar pulses, it gave no indication of range and might equally well have originated from an aircraft in the vicinity beamed by some other Würzburg. General MARTINI was fully aware at this stage that the FuGe 25 was no real solution to the identification problem.

12. Meanwhile, the firm of Gema had produced the Freya for the Navy, and in October 1939 eight of these had been taken over by the G.A.F. and were stationed on the East end North Frisian Islands, where they proved their value in combatting early British bombing attacks directed against the North Sea ports.

13. In November 1939 Gema demonstrated an I.F.F. set for use with Freya which proved to be forerunner of the FuGe 25A Erstling. General MARTINI recognised immediately that this Freya I.F.F. which operated on the principle of returning the Freya pulses and which provided range measurement, was a far superior solution and he endeavoured to use his authority to have the new principle universally adopted for Flak.

14. At that time many different departments were involved and partly on this account and partly because FuGe 25 Zwilling was sponsored by the Technisches Amt, MARTINI failed to gain his point. (see also A.D.I.(K) 334/1945), paras. 95-96). It was only with great difficulty that he was able to persuade the R.L.M. in early 1940 that an order for 3,000 FuGe 25A for Freyas should be placed and even then considerable delay occurred before they were supplied.

15. During 1940 and 1941 the shortcomings of the Zwilling gradually became apparent, particularly in connection with night fighter operations, but by the time the advantages of the FuGe 25A Erstling had been recognised and the set had been finally adopted, over 10,000 Zwilling sets had already been manufactured.

16. The original Freya used a wavelength of 2.40 metres to which the FuGe 25A Erstling responded on 1.90 metres. To permit of the universal application of the FuGe 25A a small transmitter called the Kuh had to be built into other types of early warning radar in order to interrogate the airborne set. The response was picked up by the Gemse receiver unit. In this manner a simple pair of wavelengths were, in effect, set aside for aircraft I.F.F. purposes.

17. In spite of these achievements the Flak problem had not been completely solved, as it was not possible to produce a

sufficiently beamed transmission on 2.40 metres to be certain that a response seen on the recognition tube was that of the aircraft in the Würzburg beam. Various expedients were tried out but as mentioned above, the problem still remained unsolved up to the end of the war and was finally abandoned.

#### **FUGE 25 - ZWILLING.**

18. The FuGe 25 Zwilling (= twin) received the Würzburg pulses on a 50 cm. carrier wave and re-transmitted a morse recognition signal on the same frequency, but as it did not re-transmit the pulses received, no range could be obtained by the ground set. The shortcomings of this system were recognised in 1941 and a series of attempts was made to overcome them by using responder technique as detailed below.

#### **HÄUPTLING.**

19. In order that the Flak Würzburgs should get a range with their recognition signal, the FuGe 25 Zwilling was converted so that the pulses received on 50 cm. were re-transmitted on the FuGe 25a wavelength of 1.90 m. This conversion was complete by the autumn of 1942. The new set was called Häuptling. About this time, however, Allied jamming of Würzburgs commenced and the Germans were forced to produce Würzburgs on various wavelengths known as Insel A 53.0-54.2 cm. and Insel B 56.7-58.0 cm. As a result, the FuGe 25 no longer responded to all Würzburgs and so the Häuptling did not fulfil its task.

#### **KUCKUCK.**

20. When Würzburgs on various frequencies were introduced, the basic FuGe 25 set was finally given up and the FuGe 25A Erstling became the standard airborne set.

21. All Würzburg radars were provided with a Kuh type transmitter on 2.40 m. called the Kuckuck, the aeriels for which were placed in the Würzburg paraboloid. The resultant polar diagram was extremely wide-angled as compared with the Würzburg beam and a response at the same range as that of the aircraft held in the beam was not positive proof of identity if many aircraft were about.

22. In addition the 2.40 metre transmission spilled over and could be picked up at distances of as much as 10/15 km. behind the Würzburg set, so that even aircraft behind the Würzburg were triggered off. As Flak was only interested in aircraft within firing range of the Würzburg, this procedure was at its weakest with the very type of recognition for which it had been expressly designed, and in consequence Kuckuck was finally condemned as a failure in 1943.

### WOBBELBIENE.

23. With the failure of Kuckuck the Germans decided that the only solution to the Flak problem was to apply British I.F.F. technic. The FuGe 225, known as Wobbelbiene, which was designed to sweep through (Wobbeln) the 50 cm. to 60 cm. band and act as responder (Biene), was developed for this purpose and was to have been introduced in the winter of 1943/1944. This, however, still did not cover the new Würzburg Insel C of 62.3 - 63.8 cm., which was being introduced in 1944.

24. Further modifications to Wobbelbiene were considered in order to cover this waveband but many difficulties, both mechanical and electrical, had been encountered with the design despite the fact that the set was said to be a direct copy of British R.F.3090.

25. The project was ultimately given up before being used operationally and up to the end of the war no satisfactory solution to the Flak problem had been found.

### B - I.F.F. FOR EARLY-WARNING RADAR.

26. The Kuh and Gemse arrangement in conjunction with the FuGe 25A whereby two wavelengths, 2.40 m. for interrogation and 1.90 for response, had been set aside for I.F.F., worked satisfactorily for early-warning radars. MARTINI's staff considered that this system was superior to the then current British principle of an I.F.F. set sweeping through the various early-warning wave bands and responding only intermittently to a particular frequency.

27. When Allied jamming became serious, it was fully realised that the use of one special wavelength for recognition purposes, rendered recognition very vulnerable to Allied countermeasures although it was considered difficult from a technical point of view to carry out effective jamming.

28. To anticipate this eventuality, a tactical requirement was formulated in 1943/1944 calling for a FuGe 25A working on a new frequency and the Erstling-Grün was designed and manufactured, but never put into use as the Allies did not employ the expected counter-measures.

29. With the advent, during the course of 1944, of automatic sweeping ground radar with a P.P.I. presentation like Jagdschloss, a new problem for I.F.F. arose. So long as the recognition signal emitted by the aircraft in responding was a morse letter there was no guarantee that it would come up effectively as the beam swept over the target aircraft.

30. The Germans' first solution of this problem, was the Erstling-Rot, a form of FuGe 25A, which responded with the morse identifications separated by a six-second dash, thereby ensuring that response was sufficiently continuous for the ground set to sweep the aircraft at least once whilst the airborne set was transmitting the long dash.

31. In 1944 Allied radio countermeasures became more intense and it was realised by the Germans that the general principle applied in all their anti-jamming countermeasures must also hold for I.F.F. This principle was to have a number of alternative frequencies available for every type of set and a new tactical requirement embodying this facility was, therefore, formulated.

32. It was decided that the new I.F.F. set must also give continuous presentation of the recognition response so that ground controllers could immediately identify friendly aircraft. At the same time this would solve the identification problem for panoramic ground equipment of the Jagdschloss type.

33. This requirement led to the development of the Neuling which, however, had not been used operationally up to the end of the war. It appears to have been a set with a number of novel features which are discussed below at some length.

34. In complete contradiction of the principles used in all earlier sets, the problem of I.F.F. for centimetre radar was to be solved by using the searching beam to trigger off the I.F.F. set. A small unit called the Frischling was to convert the centimetre wavelength to a frequency which would be accepted by the standard Erstling receiver.

#### **FuGe 25A - ERSTLING.**

35. The FuGe 25A is the well known set which has been installed in every German aircraft since about the beginning of 1942 and which had also been used for Egon control(see A.D.I.(K) 357/1945). It was often referred to as the Erstling.

36. It was a responding transmitter receiving on 2.40 m.(the original Freya frequency) and re-transmitting the pulses received on 1.90 metre. A morse signal repeated roughly every two seconds was superimposed on the re-transmission, six alternative codes being available. It was claimed that an advantage of using a morse letter as recognition was that it could easily be read by ear through the operator's headphones and that this was easier than following the recognition C.R. tube by eye.

#### **ERSTLING-ROT.**

37. In the early part of 1945 the G.A.F. began to introduce a form of FuGe 25A known as the Erstling-Rot. It was designed to deal with recognition difficulties occurring with ground radar of the automatic sweeping type such as Jagdschloss.

38. The Erstling-Rot separated the morse signals by a dash of six seconds duration - a period sufficient to ensure that the ground radar swept the target. It embodied an improvement in that it permitted of 18 different morse recognition signals being superimposed on the re-transmission instead of only six as in the case of the original Erstling.

39. Originally it was to have a more powerful transmitter but this requirement was allowed to lapse when it was realised that the factors limiting range were the sensitivity of the FuGe 25A receiver or the power of the ground interrogator. A project for a more powerful ground interrogator called the Gross Kuh was considered, but as the ranges obtained with the normal Kuh were thought to be adequate this idea was abandoned.

#### **ERSTLING GRÜN**

40. The G.A.F. signals staff realised that the use of a single frequency for recognition purposes exposed them to the danger of Allied R.C.M. In view of this a version of the FuGe 25A operating on a new frequency was produced which was known as the Erstling-Grün. The wavelengths used were to be 2.52 metres for interrogation and about 2.00 metres for the response.

41. The small shift in wavelength was dictated by the need to avoid new ground equipment. With the relatively small frequency change the Kuh and Gemse were capable of being adjusted to the new frequencies by the field "S. und I" (maintenance and repair) teams, and so an economy was effected.

42. Erstling-Grün was never used operationally as Allied jamming of the original Erstling frequency was never experienced.

#### **NEULING.**

43. The FuGe 226, usually referred to as the Neuling, was to have been available for installation in operational aircraft by December 1944, but owing to difficulties encountered during the trials carried out at Rechlin it was not yet ready at the time of the capitulation. Lorenz were responsible for its production and Dr. KRAMAR of that firm was considered the expert on its technical aspects.

44. The Neuling, which was considered to be a good solution to the identification problem, was designed to overcome previous difficulties and to provide new facilities. The tactical requirement originally called for were:-

(a) Continuous presentation of I.F.F. signals on all types of early-warning radar including panoramic radars such as Jagdschloss.

(b) Twelve alternative pairs of frequencies for I.F.F. (later reduced to six pairs) - each pair to consist of an interrogating and response frequency.

(c) Air to air recognition between German aircraft.

45. This ambitious programme was not fulfilled when the FuGe 226 was tried out in the later part of 1944 at Rechlin, but the experts who carried out the trials believed that the main requirements could be met by sacrificing half the pairs of frequencies, thereby limiting the set to six frequency pairs.

46. To meet requirement (a) and provide continuous presentation of the recognition signal on the ground radar, and at the same time permit the simultaneous use of a number of different frequencies, the responder and transmitter were to sweep very rapidly through the selected band which was believed to be 125 - 167 mc/s.

47. The receiver and transmitter sweeps were synchronised a few megacycles apart, so that the response was always on a slightly different frequency to that of the interrogation. This sweep was to be carried out sufficiently rapidly for the blip on the recognition tube of a ground set interrogating on one of the frequencies to appear continuous to the eye of the operator.

48. Presumably, even allowing for after-glow effects, the frequency of sweep must have been extremely high. It was not known exactly what repetition rate was used, nor what technical method was employed to obtain such a high rate of sweep through the band.

49. Great importance was attached to requirement (a) as it allowed ground controllers to obtain continuous recognition on Jagdschloss type P.P.I. tubes and so distinguish between friendlies and hostiles. It also greatly assisted the control of friendly fighters by Freya stations.

50. The requirement (a) for continuous presentation of the recognition signal appeared to have precedence over the requirement (b) for twelve alternative pairs of frequencies since in order to meet (a) Rechlin decided that the number of

channels available would have to be cut from twelve to six pairs. It was found by Rechlin that squeezing twelve separate frequencies for response (which could not overlap with interrogation frequencies) into the swept band caused the bandwidth of the individual responder frequencies to be so narrow that the recognition blip became too thin and indistinct on the ground radar recognition tube.

51. It was hoped that requirement (b) - the provision of alternative frequencies - would prove a safeguard against possible Allied R.C.M. It was also believed that it would aid in mitigating clutter on the recognition tubes of Freya etc., since interrogation would be spread over a number of frequencies. Wandering blips resulting from neighbouring ground radars which triggered off other aircraft obscured the tube and caused this clutter.

52. Efforts had also been made to overcome this trouble by building an arrangement into ground radars which prevented interrogation being carried out continuously as was often the undesirable habit of operators. By means of this arrangement power was cut off from the Kuh aerials about a minute after the interrogation switch had been depressed and this device also prevented interrogation until a further short period had elapsed.

53. Requirement (c) was only third in importance. The air to air I.P.F. facility, however, entailed a disadvantage which was regarded as a serious one, namely that when being used for that purpose the Neuling was no longer capable of responding to interrogating by other radar apparatus on the ground.

54. The tactical application of the Neuling must be considered in relation to the defence problems which the Allied bomber forces set Germany in 1944. The Germans regarded it as essential for the defence and more particularly for night defence that they should be able to obtain an absolutely clear picture of the air situation and identify Allied bomber streams unequivocally and at a glance. The P.P.I. presentation of ground radar like Jagdschloss and Forsthaus was beginning to be appreciated and attempts were being made to control directly from these panoramic displays.

55. It will be remembered too that German night fighter Gruppen operating under the Verbandsflug system flew together in loose groups or patrolled in the area of a selected beacon. It was, therefore, considered essential that these aircraft should be immediately identified as friendly on the P.P.I. tube and not confused with a bomber stream. It was also held to be of great value to ground controllers to have a means available for identifying one Gruppe from another with equal immediacy.

56. To attain these requirements one of the six interrogating frequencies available was allotted to early-warning radar and the remaining five were to be given to different night fighter Gruppen or Geschwader. The Neuling in each aircraft was then so switched that it could receive and respond to two of the six Neuling frequency pairs, viz. the early-warning frequency and the frequency allotted to the Gruppe to which the aircraft belonged.

57. For Jagdschloss panoramic ground equipment a complete continuous identification picture divided into friendlies and hostiles could be obtained by interrogating on the early-warning frequency.

58. By simply turning a knob the transmitter and receiver could be switched to the frequency pair of a particular operational Gruppe and this presented no technical difficulty with Breitband aeriels. Aircraft of that Gruppe could then be identified immediately in the over-all picture on the P.P.I. tube. This facility was considered a great advance both from the point of view of I.F.F. and of ease of ground control of night fighters.

59. P/W who claimed to have seen a ground P.P.I. display during the Neuling trials stated that the recognition blip came up on the tube as an extension of the reflected blip at slightly greater range and that it subtended a greater angle in the display. He described it as a "sausage rather longer than the aircraft blip and sitting on it".

60. Reference has been found in a document to a Neuling covering the band 1,000-1,500 mc/s. The P/W who was responsible for the formulation of radar requirements stated that he had never heard of a Neuling on this frequency, but suggested that it might be for use in responding directly to the beam of 25 cm. ground radars such as Forsthaus F. This suggestion appears unlikely, however, as it seems to involve a departure from the Neuling principle.

#### **FRISCHLING.**

61. In view of the introduction of highly beamed 9 cm. ground radar such as Forsthaus Z and Jagdschloss Z, it had been decided to depart from the principle of using a separate interrogation frequency and to employ the search beam to trigger off I.F.F.

For this purpose a special attachment to the airborne Erstling called Frischling had been planned. This was a receiver on 9 cm. which converted the frequency to that of the Erstling so that it responded on 1.90 metres.

62. With the planned introduction of the Neuling, consideration was given to a modification of the Neuling whereby a Frischling attachment would be built in for the purpose of converting the frequency and so trigger off the Neuling in the same manner. P/W was not clear whether this would only apply to one frequency of the Neuling, nor did he know what technical method would be used to accomplish it.

63. Frischling was to be produced by Telefunken but was still in course of development when the war came to an end.

#### AIR-TO-AIR I.F.F.

64. For some reason as yet unexplained, the German interest in air-to-air recognition only became great enough for suitable equipment to be designed during the last stages of the war. During the year preceding the termination of hostilities, captured night fighter crews consistently maintained that some improved form of I.F.F. which would allow recognition of friendly aircraft was expected but no attempt appears to have been made to adapt the FuGe 25A for this purpose.

65. The present P/W assert that so long as I.F.F. and air-to-air search operated on metric wavelengths and could not be sharply beamed, the problem of air-to-air recognition could only be half solved, as a range identification only was obtained. It was realised that with a dense bomber stream there would be so many aircraft comparatively near to the fighter that recognition by range only was not very valuable. Nevertheless the Neuling FuGe 226, which was shortly to be introduced, was to have provided air-to-air I.F.F. facilities.

66. In the beginning of 1945 the Germans tackled this problem for centimetric search gear and proposed to depart from their original principle of separating search and I.F.F. interrogation. The search beam of centimetre equipment was to be received by the Frischling attachment to the airborne I.F.F. set and the centimetre frequency so converted that the I.F.F. net was triggered off.

#### NEULING.

67. In the Neuling, which has been described above in detail, it was planned to provide air-to-air I.F.F. facilities by the use of a special switch which, when depressed, reversed the roles of the receiver and responding transmitter. The interrogating aircraft could then trigger off the I.F.F. set of neighbouring aircraft and receive its response on the receiver portion of the Neuling.

68. The response was to be fed through to the SN 2 or other set in use and the presentation of this recognition signal was to take the same form as in the Freya, i.e. a second time base carrying the I.F.F. signal was to appear to one side of the main time base.

69. During this operation no I.F.F. response could be made to interrogating ground stations, and this caused some apprehension. To discourage excessive use of air-to-air interrogation, the switch in the aircraft was to be awkwardly placed and inconvenient to operate - a typically German solution to a problem of aircrew training.

#### FRISCHLING.

70. The night fighter search apparatus - the Berlin N.1.A. and the Bremen 0 on 9 cm, and later probably the München on 3 cm were to go into service some time in 1945 as will be discussed in a future report in this series.

71. To provide air-to-air I.F.F. facilities the Frischling, mentioned in paras. 61-63 above, was to be attached to the FuGe 25A and later built into the Neuling as a modification. It was to convert the centimetric beam transmission of air-to-air search apparatus to the frequency of the Erstling FuGe 25A so that the latter was triggered off directly by the searching beam.

#### FALTER WITH GÄNSEBRUST.

72. As early as 1940, experiments had been made with infra-red homing on to aircraft exhausts using an infra-red telescope of the Bildwandler type called Spanner. This met with only limited success on account of restricted range and the dependency of infrared on clear weather conditions but the idea was never completely dropped.

73. With the introduction of night fighter commentary and the Verbandsflug tactics in 1944, it was required that night fighter

units should fly in groups and keep as close together as possible.

74. It was, therefore, proposed to introduce an aid in the shape of some form of infra-red navigation lights to be viewed through an infra-red telescope. The latter, which was a form of Spanner, was named Falter. As, however, the field of view of this telescope was confined to about 15° it soon transpired during trials at Werneuchen that it was not a practical proposition.

75. In 1944 the idea of using infra-red for recognition which had long lain dormant was once more evoked by the discovery that British bombers were carrying an infra-red recognition light. It was, therefore, proposed that German night fighters should home on to the infra-red lights by means of the Falter.

76. For mutual recognition between night fighters an infrared lamp termed "Gänsebrust" was also planned. It was hoped that Gänsebrust might not only allow recognition between German aircraft but possibly afford some protection from British night fighters which might become uncertain in their recognition of a German night fighter if the Gänsebrust was flashed intermittently even though the British code in use for the night were not known.

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Group Captain

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