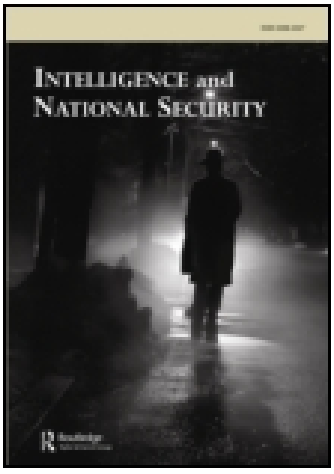

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The Infrastructure of Communications Intelligence: The Allied D/F Network and the Battle of the Atlantic

DAVID SYRETT

The best Allied source of intelligence on German activities during World War II in the Atlantic was the radio transmissions made by German U-boats. To exploit this intelligence the Allies established a network of directing finding stations around the rim of the Atlantic. When fully established the Allied direction finding network played an important role in providing the intelligence required to defeat the U-boats.

After World War II Commander Kenneth A. Knowles, USN, the head of the US Navy's U-boat tracking organization, observed that the intelligence victory over the U-boats was owing to the Allied ability to exploit, by means of radio direction finding (D/F) and decryption, the huge volume of radio communications generated by the centralized command and control system of the German U-boat service.[1]

All the German U-boat operations were commanded and controlled from a headquarters ashore, either in Germany or France, known as the *Befehlshaber der Unterseeboote* (BdU). Very rarely did a U-boat go to sea with a complete set of written operational orders. It was the BdU's standard operating procedure to send a U-boat orders and instructions, by radio, after the German vessel was already at sea.[2]

This system of command and control generated an almost endless flow of radio communications between the BdU and the U-boats at sea. In a seven day period, during February 1943, the British intercepted no fewer than approximately 262 radio messages from the U-boats attacking Convoy SC 118.[3] There are, in the American archives alone, more than 49,000 intercepted U-boat radio messages.[4] Indeed, it was this cascade of German radio messages which provided the Allies with the intelligence necessary to defeat the U-boats during the Battle of the Atlantic.

The BdU was not completely oblivious to the security risks inherent in all radio transmissions for in 1944 and 1945, after the defeat in the great convoy battles of 1943, efforts were undertaken to prevent the Allied

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interception and D/Fing of radio transmissions to and from U-boats. As a result rigid conditions of radio silence were imposed on the U-boats. One U-boat, the *U-219*, at the end of 1944, maintained radio silence for a period of 66 days and it was not unusual for U-boats to go for as long as 30 or 40 days without making a single radio signal.

Measures were also instituted to render Allied interception of the few radio transmissions that were actually made by the U-boats much more difficult to intercept. The length of radio transmissions was greatly reduced. In December 1944, for instance, 90 per cent of all U-boat radio transmissions were of a duration of 30 seconds or less.

And in the autumn of 1943 the BdU adopted a system, known to the Allies as 'Norddeich off frequencies', in which, in order to increase the difficulties of interception, radio messages would be transmitted on prearranged schedules, just off the normal radio frequencies employed by the U-boats.[5]

However, these security procedures were instituted too late in the war to effect the outcome of the Battle of the Atlantic, for while hindering and making the task of Allied D/F and intercept stations more difficult, they were half-way measures that did not address the root cause of the problem which is that all radio transmissions are potential breaches of security.

The BdU knew that there was a logical possibility that the Allies could obtain intelligence from radio transmissions to and from U-boats. Nevertheless, the BdU tended generally to discount the security dangers inherent in all radio communications and continued to employ, throughout the war, a command and control system requiring a large number of radio transmissions.[6] Not only was it believed by the Germans that their codes were so complex that the Allies could never decrypt an encoded radio message in time to be of operational use,[7] but it was also a firmly-held conviction by the BdU that it would be nearly impossible for the Allies to D/F, systemically and accurately, extremely short high-frequency radio transmission.[8]

It was only after World War II that the Germans learned that both of these beliefs were ill-founded for not only could the British and the Americans decrypt encoded U-boat radio messages, but the Allies could also systematically and accurately D/F U-boat radio messages. This was a major German intelligence failure. Indeed, the reasons why the BdU and other German command and intelligence authorities failed to see the possibility that the Allies might develop the ability to D/F high frequency radio transmissions and break complex codes are at best obscure.[9]

This oversight by the Germans is even harder to comprehend in the light of the significant role of communications intelligence in the fight against the U-boats during World War I.[10]

Among popular writers as well as naval historians, including the present writer,[11] decryption intelligence usually takes pride of place compared to D/F. This attitude is in some respects difficult to understand for not only did D/F supplement decryption intelligence, by giving the approximate position of a U-boat making a radio transmission, but on many occasions D/F was the only timely communications intelligence available to the Allies on the activities of U-boats. For long periods of World War II the Allies could not decrypt and read U-boat radio messages.

Moreover, when the Allies were decoding and reading U-boat radio messages there were always delays and lags in the decryption process which meant that hours, and in many cases days, would pass between the time when a German radio message was intercepted and the time when the plaintext of a message was available for inspection by Allied intelligence officers.[12] For example, in August 1941, during the battle for Convoy OG 71, two days,[13] and in some cases six or seven days,[14] elapsed owing to delays in the decoding process, between the time of interception of a message sent by a German U-boat and the time of decryption by the British. In such cases, D/F was not only a principal source but, on many occasions, it was the only source of information available to the Allies on the activities of German U-boats in the Atlantic.

Radio direction finding is the taking of several bearings, from different positions, on the source of a radio transmission. The intersection of the bearings, as plotted on a chart, that results, indicates the approximate location of the site of the transmission.[15] To obtain a proper plot of the position of a radio transmitter, several bearings – at least three and one of them at an acute angle to the others – had to be taken simultaneously by several different D/F stations. Before World War II, the Allies did not have the necessary infrastructure, in terms of D/F stations and high speed electronic communications, to obtain the signals intelligence required for a major naval conflict in the Atlantic. In 1937 there were, world-wide, only four Royal Navy D/F stations located at Flowerdown (north Devon) in Britain, Gibraltar, Malta, and Hong Kong.[16]

Further, the major naval threat to Britain in the late 1930s was perceived by many in the Royal Navy not to be U-boats, but rather German surface raiders.[17] As late as 1939 the Director of the Admiralty's Signal Department was resisting the establishment of additional D/F stations in the Atlantic region because 'It is anticipated that an enemy raider will make very few, if any, W/T signals.'[18]

Nevertheless, at the instigation of the Government Code and Cypher School and the Naval Intelligence Division of the Admiralty, the Royal Navy began to see the importance of a network of D/F stations around the rim of the Atlantic.[19] It was by then becoming a 'definite target' of the

British to be able to intercept every enemy radio signal no matter where it originated.[20]

So in the months before the beginning of World War II the Royal Navy undertook a crash program to establish the D/F stations required to obtain bearings of radio transmissions throughout the Atlantic region. Plans were made for the erection of D/F stations, not only in Britain, but also in British colonies, such as Bermuda, St Helena, Sierra Leone, Jamaica, and British Guiana. Further, the governments of South Africa and Canada were approached with the view of establishing D/F installations at the Cape of Good Hope and Nova Scotia.[21]

Owing to the vagaries of radio waves, the sites of these new D/F stations had to be chosen with care. Ideally a D/F station should be located on 'a flat open piece of land, about half-mile in diameter, of uniform soil surface and not near the sea'. The area should be free of buildings, streams, high tension wires, and trees.[22] To facilitate the rapid transmission of bearings to the Admiralty in London, overseas D/F stations were to be connected to the local overseas cable office by direct telephone links. Most of the Royal Navy's D/F stations would be manned by members of the Civilian Shore Wireless Service.[23]

When World War II broke out the work of building such stations had only begun. For early September 1939, the Royal Navy's network of D/F stations consisted of establishments, which were equipped with modern high frequency direction finding [HF/DF] equipment located in the Shetland Islands, Scarborough, Flowerdown, Cuper (Fife, Scotland), and Land's End in the British Isles as well as stations overseas in the West Indies, West Africa, and Gibraltar.[24]

By the spring of 1942 the Royal Navy's system of D/F stations had grown into a network of 18 establishments in the United Kingdom as well as a further 18 stations abroad in Canada and South Africa.[25]

By the end of the war these British D/F stations would be manned by approximately 1,327 operators.[26] When the Allied naval D/F system in the Atlantic region had been fully developed it would consist of a very large number of stations manned by Britons, Canadians, and Americans.[27]

Radio direction finding was invented before World War I and came of age during that conflict. In the two decades between the world wars investigations by physicists into subjects, such as the propagation of radio waves, led to many improvements and refinements in the technology of D/F, such as the introduction of the Adcock aerial.[28] At the beginning of World War II, as a result of such technological advances, the British replaced medium frequency D/F sets in their intercept stations with high frequency or HF/DF sets.[29]

This new equipment was either manufactured by firms in Britain, such as the Marconi Company, or was purchased in the United States. HF/DF,

like radar, was a spin-off from research into the nature of the ionosphere by means of radio equipment displaying images on cathode tubes. Unlike medium frequency D/F, HF/DF could obtain bearings at great ranges on high frequency radio transmissions made by U-boats at sea.[30] It required highly skilled and patient personnel to man the Allied D/F stations. For the operators had to sit, day after day, waiting to take a bearing on a U-boat transmitting very short encoded radio messages, in faint Morse, sounding in fact like so much gibberish.[31]

It was quickly discovered by the British, as well as by the Canadians and Americans, that it was 'essential to *centralize our interceptions*' by means of high speed electronic communications.[32] All Allied D/F networks in the United Kingdom, Canada, and the United States, that covered the Atlantic region, transmitted electronically for plotting all bearings, which were obtained on U-boat radio transmissions, either to Washington DC, London or Ottawa.[33] Because an operator of a D/F sent could only monitor one frequency at a time, all the naval D/F stations in Britain, as well as in the United States and Canada, were linked by a telephone system to other monitoring stations whose task it was to 'tip off' the D/F stations as to which frequency to tune in on, so as to obtain a bearing on a radio transmission.

The system in Britain was given greater flexibility by being also connected, by telephone, to the D/F networks of other services, such as the Royal Air Force, so that in an emergency the Navy's ability to obtain bearings could be supplemented. This system of 'tip offs' could produce, from the D/F stations in Britain, 'as many as twenty bearings on any particular transmission'.[34]

All the D/F stations in Britain, Canada, and the United States were further linked by high speed electronic communications to central plotting rooms in either London, Ottawa, or Washington. When the system had been fully developed it took a mere six minutes, from the time of transmission, for a D/F bearing to reach the Atlantic Section of Combat Intelligence, Office of Cominch [Commander-in-Chief US Fleet] in Washington DC.[35]

Such speed of communications was not achieved easily. In the first years of the war, one of the problems was the inability to quickly transmit D/F bearings, as well as other signals intelligence information, from overseas intercept stations to Washington and London. In 1939 the British intended to rely upon the Empire-wide system of submarine cables managed by such firms as the Cable and Wireless Company. However, submarine cables, as well as regular naval radio systems, were soon found to be inadequate and subject to delays owing to the fact that the raw materials of signals intelligence, such as D/F bearings, had a lower priority than other messages.[36] For example, in early 1942, it would take nearly an hour for a bearing to be

transmitted from London to Washington DC, about two hours from Bermuda or Halifax, Nova Scotia, and five hours from other parts of Canada.[37]

To resolve this problem and others, at the instigation of the British, a meeting was held of British, Canadian, and American experts on communications intelligence in Washington DC, in April 1942. The objective of the meeting was to integrate and rationalize the collection and distribution of communications intelligence. One of the key decisions of this meeting was to set up a worldwide communications network whose sole purpose was to carry communications intelligence information such as D/F bearings.[38]

The mechanisms, which were worked out as a result of this decision, not only connected, by means of high-speed electronic communications, all Allied D/F stations to the central plotting rooms in either London, Ottawa, or Washington DC, they also permitted the exchange between the three plotting rooms, by high speed direct line teletype, of D/F bearings and fixes within 15 or 20 minutes after transmission.[39]

In 1943, the British decided to reorganize the Royal Navy's network of D/F stations by concentrating them into groups. According to this scheme the North Atlantic would be covered by eight groups of D/F stations. Each of these groups would consist of five D/F stations located in the United Kingdom, and one group each in Iceland, Nova Scotia, Jamaica, and Morocco. A bearing could be obtained on a radio transmission by calculating the average bearing from all five D/F stations in a group. This mean bearing would then be transmitted to London by special radio links.[40]

The concept of grouping D/F stations grew out of the practice in Britain of calculating mean bearings from a northern group of D/F stations (Shetlands, Wick, Cuper), then from stations in northern England (Scarborough and Portrush), and then from a third set of stations located in the south of England (Lydd, Flowerdown, and Land's End). These three mean bearings, when plotted, gave a 'beam' with a width of between 25 and 50 miles. When checked against decryption intelligence, 'The resultant cut gave what was thought to be a 90 per cent probability area.'[41] It was believed that this new system would result in greater accuracy of the bearings obtained and faster transmission of the bearings to London while at the same time it would ease the problems of plotting bearings.

Another reason for this alteration was the desire among the British, especially the director of the Admiralty's Signals Department, to dispense with D/F bearings provided by the Americans. For the British considered, for reasons which are not wholly clear, that 'U.S. bearings are almost wholly valueless'. They further believed that one of the advantages of grouping D/F stations would be the ability to thus obtain increasingly

accurate D/F bearings, without the assistance of the Americans, covering the whole North Atlantic region.[42]

Once the British had established several clusters of HF/DF stations and put them in operation, it was found that there was no great increase in the accuracy of bearings. In fact some people would argue that the new system of grouping D/F stations probably resulted in less accurate bearings. In the judgement of the D/F plotters in the Admiralty, the reason the 'method was not so successful', was that the D/F stations in each group, being located adjacent to each other, 'would all receive the same distortion of reflected rays'.

Further, many of the D/F stations had individual idiosyncrasies which in turn produced additional desortions in the mean bearings. In the end the accuracy of a D/F bearing did not depend upon schemes, such as the grouping together of D/F stations, but rather on the placing the D/F set in a location free from radio wave propagation problems as well as on the ability and training of individual operators of D/F sets, and on the skill of the D/F plotter.[43]

All D/F bearings in Britain were plotted by Section 8(X) of the Admiralty Operational Intelligence Centre. The bearings which were dispatched to Section 8(X), either by telephone or teletype, were, if possible, accompanied by a note indicating the type of message transmitted. As one British signals intelligence officer remarked, 'a great deal can be obtained from the study of enemy wireless traffic without having the faintest idea of the contents of the message'.

From characteristics such as length, callsigns and format, the Allies could on many occasions tell if a radio message from a U-boat was a passage, sinking, sighting, weather, contact, or position report.[44] For example, many U-boat sighting reports, which were made by short signals, were pre-fixed by what the Allies called an E-bar. That is, an alpha in German morse and rendered dot dot dash dot dot.[45] This type of information, when combined with D/F fixes, could not only provide the approximate location of a U-boat, but could also provide some indications of the enemy' vessel's activities.

Section 8(X), at the beginning of World War II, was located in the basement of the Admiralty; it subsequently moved, along with the Submarine Tracking Room and the rest of the Operational Intelligence Centre, to the Citadel bunker adjoining the Admiralty. Throughout the war, Section 8(X) was commanded by Lieutenant Commander Peter Kemp, RN (ret.) and manned by three male civilians.[46] In 1942 four female assistants[47] were added to the staff of 8(X). For the whole war Section 8(X) shared the same room in the Operational Intelligence Centre as the submarine trackers which gave the D/F plotters easy access to the positions of U-boats as revealed by decryption intelligence.[48] After the war Kemp maintained, as was the case with the Canadian D/F plotters in Ottawa, that a superior

arrangement would have been for the British D/F plotters, while working on D/F fixes, for them not to have had a ready knowledge of a U-boat's position from the submarine tracker's operational plot.[49]

As far as locating the position of a U-boat was concerned, the remark that 'fixing a position is more and art than a science',[50] was not far from the truth. For the accuracy of a D/F plot obviously depended not only on the accuracy of the bearings provided by the D/F stations, but also on the skill of the person doing the plotting. During the war, Kemp and his assistants, using various ingenious methods involving pins, pulleys, cords and weights, showed great skill in the art of fixing a U-boats position by plotting the bearings of radio transmissions on a chart. 'Very good' was a fix within 10 or 15 nautical miles and a 'good fix' was within 40 or 50 miles.[51]

However, most D/F fixes could only place the location of a U-boat making a radio transmission within a rectangle of some 50 or 200 miles or within an area of 10,000 square miles.[52] Nevertheless, 'Even appallingly bad fixes – "within 200 miles or" – and the like – served their purpose and if one could not get a fix [at] all [from] one set of bearings, it was possible to assert with remarkable confidence that a set of bearings, poor as they were, certainly did id *not* emanate from such and such a area.'[53]

The Allies in 1944 and 1945 often found it possible, utilizing the vaguest of clues from communications intelligence and dead reckoning, to employ successfully hunter-killer groups, especially anti-submarine warfare (ASW) aircraft, to hunt down and sink an enemy vessel.[54] Obviously the plotting of D/F positions in the final analysis remained less than perfect, limited by the parameters of the 1940s electronic technology and the skill of D/F set operators as well as D/F plotters.[55]

In World War II, the Allies made a huge investment in infrastructure, by setting up some 50 D/F stations in the Atlantic region, all connected by high-speed electronic communications, in order to obtain D/F bearings to fight the war against the U-boats. That this investment was necessary there can be no doubt. For shore-based D/F stations ultimately enabled the Allies to determine the approximate location of U-boats at sea. Even with degrees of accuracy D/F fixes were of vital importance to the Allies in fighting the Battle of the Atlantic.[56]

In the absence of decryption intelligence, D/F fixes were one of the few ways, if not the only way, in which the Allies could gain knowledge of the activities and locations of the U-boats during World War II. Even when decryption intelligence was available, D/F fixes could still be of vital importance to the Allies. Information from D/F became available to the Allies in a timely fashion, and was not subject to the delays, owing to the decoding process, associated with decryption intelligence.

Moreover, D/F provided three types of information which, whether taken singly or together, were vital to the war against the U-boats. In the final analysis D/F gave the Allied command authorities the information necessary to warn ships and convoys of the presence of U-boats; the information required to be able to route Allied ships and convoys away from the danger of attack by U-boats; and last but not least information which could be used to dispatch ships and aircraft to hunt down and destroy U-boats.[57] Shore based D/F, was more than just a method by which the Allies obtained intelligence. It was a tool that was vital to victory in the war against the U-boats.

NOTES

1. Public Record Office, ADM 223/297, OIC and Special Intelligence Monographs. Hereafter the Public Record Office will be cited as PRO.
2. National Archives, Record Group 457, SRMN-032, Memoranda concerning U-boat Tracking Room operations, f.009. Hereafter the National Archives and Record Group 457 will be cited as NA.
3. PRO, ADM 223/16, ff.41-46.
4. NA, SRGN-001/49668, German Navy/U-boat Message Translations.
5. NA, SRMN-051A, OP-20-GI Memoranda to Cominch F 21 on German U-boat Activities, Oct. 1943 – May 1945, pp.146–8.
6. Karl Doenitz, *Memoirs: Ten Years and Twenty Days* (NY: World Publishing 1959) pp.62–3.
7. Jurgen Rohwer, 'Ultra and the Battle of the Atlantic: The German View', *Changing Interpretations and New Sources in Naval History*, Robert William Love, Jr (ed.) (NY: Garland 1980) pp.420–1.
8. Doenitz, *Memoirs* (note 6) p.63.
9. Cf. David Kahn, *Hitler's Spies: German Military Intelligence in World War II* (NY: Macmillan 1978) pp.523–43.
10. Cf. R.M. Grant, *U-Boat Intelligence, 1914–1918* (NY: Putnam 1969).
11. Cf. David Syrett, *The Defeat of the U-boats: The Battle of the Atlantic* (Columbia: Univ. of South Carolina Press 1994).
12. PRO, HW 11/38, ff.7-8.
13. E.g., PRO, DEFE 3/25, intercepted 1757/16/8/41 decoded 2237/18/8/41.
14. E.g., PRO, DEFE 3/26, intercepted 2308/18/8/41 decoded 1616/25/8/41.
15. Cf. Charles Cotter, *The Principles and Practice of Radio Direction Finding* (London: Pitman 1961).
16. PRO, ADM 223/297, OIC and Special Intelligence Monographs.
17. PRO, ADM 1/9822, Record of Conversations between Captain Ingersoll, USN, and the Naval Staff at the Admiralty, 1937–38.
18. PRO, ADM 1/9529, Minute by DSD, 16 June 1939.
19. PRO, ADM 1/9529, Minute by DNI, 29 Dec. 1939.
20. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, Appendix ii, pp.2–3.
21. PRO, ADM 1/9529, Minute by DNI, 20 Dec. 1938; ADM 1/10648, Proposals by the DNI and DSD, 19 Aug. 1939.
22. PRO, ADM 1/10648, Report on Selection of Sites for Spaced-Aerial Direction-Finders, 19 Oct. 1936. See also William Ross and Frederick Horner, *The Sighting of Direction Finding Stations* (London 1952).
23. PRO, ADM 1/10648, Admiralty to Commanders-in-Chief America, West Indies, and South Atlantic…, 21 Oct. 1939.
24. PRO, HW 3/147, f.2.

25. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, Appendix iii, pp.5–6.
26. PRO, ADM 223/463, NID(9) Wireless Intelligence.
27. NA, SRH-277, A Lecture on Communications Intelligence by Rear Adm. E.-E. Stone, 5 June 1952.
28. R. Keen, *Wireless Direction Finding* (London: Iliffe, 4th ed. 1947) p.9.
29. Cf. PRO, ADM 223/297, Special Intelligence.
30. Brian Johnson, *The Secret War* (London: BBC 1973) pp.210–12.
31. The only account of the operations of an Allied radio intercept station is Edward J. Drea, *In the Service of the Emperor: Essays on the Imperial Japanese Army* (Lincoln: Univ. of Nebraska Press 1988) pp.110–26.
32. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, Appendix iii, p.6.
33. PRO, ADM 223/297, OIC and Special Intelligence.
34. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, Appendix iii, pp.5–6.
35. NA SRH-197, US Navy Communications Intelligence Organization, Liaison, and Coordination, 1941–1945.
36. PRO, ADM 223/184, Expansion of 'Y' Service, 5 Jan. 1942.
37. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, Appendix iii, p.11.
38. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, pp.3–13.
39. PRO, ADM 223/297, The D/F plotting Section of the OIC, p.5.
40. PRO, ADM 1/13070, U-Boat Attacks – Use of HF/DF; Minutes by DSD and DNI, 17–22 April 1943; ADM 1/13042, Jamaica Anti U-boat HF/DF Stations, Admiralty to ACIC, SBNO Western Atlantic, 12 June 1943.
41. PRO, HW 3/147, ff.3-4, 5.
42. PRO, ADM 13070, U-boat Attacks … Use of HF/DF; VCNS Groupings of H/F D/F Stations, nd.
43. PRO, HW 3/147, ff.3-4, 5.
44. PRO, ADM 223/285, British-Canadian-American Radio Intelligence Discussions, 6–17 April 1942, Appendix iii, pp.9–10.
45. Cf. Ralph Erskine, 'Kriegsmarine Short Signal Systems – and How Bletchley Park Exploited them', *Cryptologia* 13 (June 1999) pp.65–92.
46. D.F.N Fitzgerald, F. Martin Vaughan, and C. Caddy.
47. B. Llewllyn, C. Church, P. Tweedee, J. Lewis-Smith.
48. PRO, ADM 223/237, D/F Plotting Section of the OIC, p.1.
49. PRO, HW 3/147, f.7.
50. NA, SRH-277, Lecture on Communications Intelligence…
51. PRO, ADM 223/297, The D/F Plotting Section of the OIC, pp.2–5.
52. Ralph Erskine, 'Afterword: Codebreaking in the Battle of the Atlantic', in Patrick Beesely, *Very Special Intelligence: The Story of the Admiralty's Operational Intelligence Centre, 1939–1945* (London: Greenhill 2nd ed. 2000) p.272.
53. PRO, ADM 223/297, The D/F Plotting Section of the OIC, p.5.
54. Cf. David Syrett, 'Communications Intelligence and the Sinking of the U-860, April–June 1944', *The Mariner's Mirror* 90/1 (Feb. 1999) pp.68–75.
55. For an account of the methods and problems of plotting D/F bearings see Keen, *Wireless Direction Finding* (note 28) pp.659–755.
56. NA, SRMN-032, Memoranda Concerning U-boat Tracking Room Operations, 2 Jan. 1943 – 6 June 1945, f.098.
57. Cf. PRO, ADM 223/297, D/F Plotting Section of the OIC, p.6.