

# COOLING RADIO STATION, HOO PENINSULA, KENT AN ARCHAEOLOGICAL INVESTIGATION OF A SHORT-WAVE RECEIVING STATION

Derwin Gregory and Sarah Newsome



*This report has been prepared for use on the internet and the images within it have been down-sampled to optimise downloading and printing speeds.*

*Please note that as a result of this down-sampling the images are not of the highest quality and some of the fine detail may be lost. Any person wishing to obtain a high resolution copy of this report should refer to the ordering information on the following page.*

## COOLING RADIO STATION HOO PENINSULA, KENT

### An Archaeological Investigation of a Short-Wave Receiving Station

Derwin Gregory and Sarah Newsome

NGR: TQ 7730 7675

© English Heritage

ISSN 1749-8775

*The Research Department Report Series incorporates reports from all the specialist teams within the English Heritage Research Department: Archaeological Science; Archaeological Archives; Historic Interiors Research and Conservation; Archaeological Projects; Aerial Survey and Investigation; Archaeological Survey and Investigation; Architectural Investigation; Imaging, Graphics and Survey, and the Survey of London. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series and the Architectural Investigation Report Series.*

*Many of these are interim reports which make available the results of specialist investigations in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Where no final project report is available, readers are advised to consult the author before citing these reports in any publication. Opinions expressed in Research Department reports are those of the author(s) and are not necessarily those of English Heritage.*

Requests for further hard copies, after the initial print run, can be made by emailing:

Res.reports@english-heritage.org.uk

or by writing to:

English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD

Please note that a charge will be made to cover printing and postage.

## **SUMMARY**

In August 2010, English Heritage's Archaeological Survey and Investigation team carried out an investigation of the remains of Cooling Radio Station. The station was constructed in 1938 to house the 'Multiple Unit Steerable Antenna' (MUSA) system developed by Friis and Feldman in the 1930s. The MUSA array was the last major technological development in the short-wave communication era and represented the ultimate short-wave receiving system. It is believed that only two other stations using the MUSA system were built in the world: the experimental array constructed near Holmdel, New Jersey, and one other full array at Manahawkin, New Jersey. Unlike the mechanical operating system employed at Manahawkin, Cooling Radio Station was unique as it was controlled by an electrical phase-shifting system. In total, the receiving equipment at Cooling utilised 1,079 valves making it both complicated and expensive. The MUSA system was probably the most complex radio receiver ever built and gave valuable service between the 1940s and 1960s. Prior to the rise of satellites and the end of the short-wave era, an experimental short-wave receiving system was constructed at Cooling. The 'Multiple Direction Universally Steerable Aerial System' (MEDUSA) had the potential to be the next major development in global short-wave communication. During the early years of the Second World War, an Admiralty direction finding (D/F) station was located near to the apparatus building at Cooling. This station was part of a network which played a vital role in the war against the U-boats.

## **CONTRIBUTORS**

The field survey was carried out by Sarah Newsome (Senior Archaeological Investigator), Rebecca Pullen (Archaeological Investigator), and Derwin Gregory (EPPIIC Placement) of English Heritage's Archaeological Survey and Investigation team, with assistance from Trevor Pearson, Head of Technical Survey and Graphics. The archaeological background and historical sources were researched by the principal author, Derwin Gregory. The text was edited by Sarah Newsome. Earthwork plans and other illustrations were drawn by Derwin Gregory. Professional photography was undertaken by Steve Cole.

## **ACKNOWLEDGEMENTS**

English Heritage would like to thank the RSPB for allowing access to Cooling Radio Station. Thanks also go to Brian Collins, Frank Turner, Malcolm Hancock, Norman Williams and Andrew Williams who all provided useful information. The authors would also like to thank staff at the BT Archives and The National Archives for their kind help.

## **ARCHIVE LOCATION**

Copies of this report have been deposited in the English Heritage archive and library at the National Monuments Record Centre (NMRC), the BT Archives, the British Postal Museum and Archive and Kent County Council's Historic Environment Record.

## **DATE OF SURVEY**

The field survey was carried out between 3 and 6 August 2010 and the aerial photographic transcription was undertaken between 29 November and 3 December 2010.

## **CONTACT DETAILS**

English Heritage, Brooklands, 24 Brooklands Avenue, Cambridge, CB2 8BU  
Sarah Newsome Tel. 01223 582771. Email: [sarah.newsome@english-heritage.org.uk](mailto:sarah.newsome@english-heritage.org.uk)

# CONTENTS

INTRODUCTION	I
PREVIOUS RESEARCH	3
DOCUMENTARY EVIDENCE FOR THE HISTORY OF THE SITE	4
Transatlantic Communications	4
The Post Office and the American Telegraph and Telephone Company (AT&T)	8
Identifying a Suitable Site	9
Purchasing Land at Cooling	12
The Apparatus Building	16
Construction	18
Technical Details	22
Rex of Ware	28
Admiralty Direction Finding (D/F) Station	29
The Second World War	34
Post-Second World War	35
The 'Multiple Direction Universally Steerable Aerial System' (MEDUSA)	38
The Experimental MEDUSA at Cooling	41
Cooling Airport	43
CSA Ltd	45
DESCRIPTION AND INTERPRETATION OF THE REMAINS	46
Apparatus Building Survey	46
Topographical Survey of Environs	54
Historic Aerial Photography Mapping	56
DISCUSSION AND CONCLUSION	59
SURVEY METHODOLOGY	60
GLOSSARY	61
REFERENCES	65

## ILLUSTRATIONS

Figure 1: Location map.	1
Figure 2: Cooling Radio Station under construction.	2
Figure 3: Ionospheric multi-path transmission.	4
Figure 4: Waves cancelling each other out.	5
Figure 5: Rhombic antenna.	6
Figure 6: View of the experimental MUSA system located at Holmdel, New Jersey.	7
Figure 7: Table showing the increase in messages sent over the TAT.	8
Figure 8: Map showing the sites identified as potentially suitable for the MUSA.	10
Figure 9: Proposed layout of the apparatus building.	16
Figure 10: Cooling Radio Station apparatus building.	17
Figure 11: Feeder termination chamber under construction.	19
Figure 12: Laying the feeder tubes.	19
Figure 14: Transatlantic telephone link during the Second World War.	20
Figure 13: Photograph showing one of the pair of gates which the Post Office erected.	20
Figure 15: Image looking along the MUSA during construction.	22
Figure 16: Diagram showing the design of the rhombic antenna at Cooling.	23
Figure 17: Three-legged spacing insulator.	23
Figure 18: MUSA phase shifter at Manahawkin.	24
Figure 19: Equipment at Cooling Radio Station.	25
Figure 20: MUSA receivers at Manahawkin.	26
Figure 22: Plan of the steerable antennae at Holmdel, New Jersey.	27
Figure 23: Plan showing the possible broadside MUSA at Cooling.	28
Figure 24: Cross section of a D/F hut.	32
Figure 25: Proposed layout of the D/F station at Cooling.	33
Figure 26: Armed guard outside Cooling Radio Station.	34
Figure 27: Boundary of the proposed Nature Reserve.	35
Figure 28: The tower the PO intended to erect in Cooling Marshes.	37
Figure 29: Schematic diagram of a MEDUSA.	39
Figure 30: The MEDUSA at Cooling mapped from aerial photographs.	40
Figure 31: The aerials which made up the MEDUSA.	42
Figure 32: Schematic diagram of experimental MEDUSA.	42
Figure 33: One of the plans for an international airport and flying boat base.	44
Figure 34: The remains of Cooling Radio Station.	46
Figure 35: Remains of the apparatus building.	47
Figure 36: Photograph showing the two rooms beneath the western bay.	48
Figure 37: The main chamber of the basement.	49
Figure 38: Photograph showing the main entrance to Cooling Radio Station.	50
Figure 39: Photograph showing the paved terrace platform and the generator room.	51
Figure 40: The eastern elevation of the remains of Cooling Radio Station.	53
Figure 42: The concrete slab indicates the location of a demolished structure.	55
Figure 43: Aerial photographic transcription of Cooling Radio Station and environs.	56
Figure 44: Aerial photograph showing the apparatus building and the part of the MUSA.	58
Figure 45: The process of amplitude modulation.	61
Figure 46: Phase difference between two identical signals.	63
Figure 47: Survey of the remains of the apparatus building.	69

<i>Figure 48: Topographical survey of Cooling Radio Station.</i>	70
<i>Figure 49: Aerial photographic transcription of Cooling Radio Station and environs.</i>	71
<i>Figure 50: Structural survey of the remains of the apparatus building.</i>	72
<i>Figure 51: Structural survey of the generator room.</i>	73

AT&T:	American Telephone and Telegraph Company
BT:	British Telecommunications
c/s:	Cycles per second
D/F:	Direction Finding
GPO:	General Post Office
GPS:	Global Positioning System
kW:	Kilowatts
MEDUSA:	Multiple-Direction Universally-Steerable Aerial System
MUSA:	Multiple Unit Steerable Antenna
NHPP:	National Heritage Protection Plan
PO:	Post Office
RSPB:	Royal Society for Protection of Birds
RTK:	Real Time Kinetic
TAT:	Transatlantic Telephone
VRS:	Virtual Reference Station



## INTRODUCTION

The investigation into Cooling Radio Station was carried out as part of English Heritage's ongoing 'Hoo Peninsula Historic Landscape Project' (RASMS 5733). Through research for the 'Hoo Project', the remains of Cooling Radio Station were identified as a poorly understood heritage asset. The RSPB also wished to know more about the history of the building in order to inform its future reuse through Higher Level Stewardship funding. The principal aim of the investigation at Cooling Radio Station was to substantially increase our knowledge and understanding of the role it played in twentieth-century wireless communications (Gregory 2010). It was also the aim of this investigation to understand and record the surviving remains at Cooling. The theme of transport and communication has been identified by English Heritage's draft National Heritage Protection Plan (NHPP) as a possible future area of research (English Heritage 2010).



Figure 1: Location map.

Cooling Radio Station is located just above sea level to the south of Buckland Marsh on the Hoo Peninsula, Kent, within the parish of Cooling which is part of the Medway Council Unitary Authority. To the south-east and south-west, the land rises to 65m and 40m respectively (Figure 1). Approximately 2.5km to the north, the River Thames flows past Canvey Island and into the North Sea. Currently, the site is owned by the RSPB and

within the Northward Hill Reserve (Gregory 2010).

To date, a number of projects have examined the landscape of the Hoo Peninsula, including: the North Kent Rapid Coastal Zone Assessment Survey (Wessex Archaeology 2006); the Thames Gateway Characterisation; the Kent Historic Landscape Characterisation; and the Greater Thames Estuary Archaeological Research Framework (Williams and Brown 1999). However, the only research on Cooling Radio Station has been undertaken by Mr Frank Turner and his work can be seen in the self-published booklet 'Cooling Radio Station' (2000).



*Figure 2: Cooling Radio Station under construction (still from Jennings 1938 © Royal Mail Group Ltd 2011, courtesy of The British Postal Museum & Archive).*

Given the lack of previous research, various non-intrusive investigative techniques were employed to understand the site. Topographical survey, building recording, and aerial photographic transcription were carried out by English Heritage's Archaeological Survey and Investigation team between August and December 2010. Cooling Radio Station's environs were surveyed at 1:1000 to Level 3 standard (as defined by English Heritage 2007, 23-4) and aerial photographic transcription undertaken at 1:2500. Today, all that remains of Cooling Radio Station is the main platform, basement and generator room.

## PREVIOUS RESEARCH

Prior to the research for this report, the only investigation into Cooling Radio Station was conducted by Mr Frank Turner. The results of this work can be found in Mr Turner's self published booklet entitled 'Cooling Radio Station'. In August 2010, The Morton Partnership Ltd were commissioned by the RSPB to undertake a structural survey of Cooling Radio Station (The Morton Partnership Ltd 2010).

## DOCUMENTARY EVIDENCE FOR THE HISTORY OF THE SITE

### Transatlantic Communications

At the turn of the 20th century, transatlantic communication was dominated by the submarine cable telegraph. In an attempt to challenge this monopoly, Marconi established an experimental transmitter station at Poldhu on the Lizard Peninsula, Cornwall, and a receiver station at St Johns, Newfoundland. On the 12 December 1901, the first wireless transatlantic communication was achieved (Bray 2002, 71).

Until the 1920s, transatlantic wireless communication was restricted to a few powerful spark transmissions operating in the very long-wave spectrum (Hawkins 1995, 147). However, the limitations of long-wave communication were apparent. To transmit long waves across the Atlantic, transmitter power was substantial, antennae systems were excessively large, and there was limited space available in the frequency spectrum for more than a handful of telegraph services. It was also impractical to concentrate long wavelength energy into beams (Bray 2002, 73).

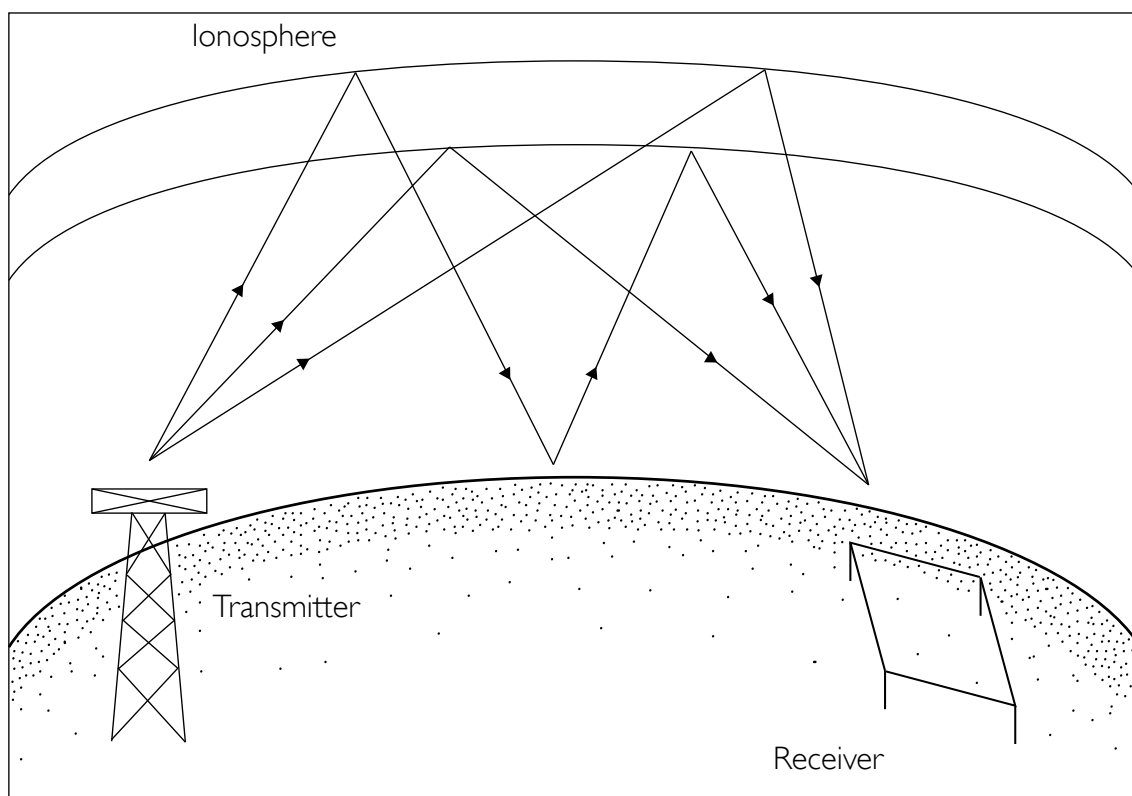


Figure 3: Ionospheric multi-path transmission.

In 1916, Marconi arranged for CS Franklin to conduct a series of experiments into the commercial potential of short-wave communication (Hawkins 1995, 148). By 1924, Franklin was transmitting a good signal from Poldhu to New York on a 100m wavelength using only 20kW of power. In May of the same year, short-wave communication enabled

speech to be successfully transmitted from England to Australia for the first time. The era of short-wave point-to-point communication commenced in September 1929 when Bell Laboratory officials in New York, in conjunction with the British Post Office, talked to Australia via London (Bray 2002, 75, 77).

Short wavelengths ushered in a new era of transatlantic communication: antennae could be constructed on a moderate scale, reducing cost, increasing efficiency and reducing the power required for reliable communications. Communication using short wavelengths also opened up a wide range of frequencies enabling the growth of radiotelegraph and radiotelephone circuits (Bown 1937, 1128). However, short-wave communication also had inherent problems (Hawkins 2004, 3). Short-wave signals arrive at the receiver from a number of directions as a result of 'bouncing' between the surface of the earth and the ionosphere (Figure 3; Pierce and Posner 1980, 167). This multi-path transmission could cause speech distortion and selective fading (Bray 2002, 77). To overcome this, Bell Telephone Laboratories commenced work in 1935 on a 'Multiple Unit Steerable Antenna' (MUSA) (Hawkins 2004, 3-4). The development of the MUSA was the last major technological development in the short-wave era (Bray 2002, 77).



Figure 4: Waves cancelling each other out (still from Jennings 1938 © Royal Mail Group Ltd 2011, courtesy of The British Postal Museum & Archive).

## The 'Multiple Unit Steerable Antenna' (MUSA)

As described above, during the operation of short-wave radiotelephone circuits, transmission fading can occur. Fading is caused when waves travelling along different paths arrive at the receiver and cancel each other out (Figure 4; Polkinghorn 1940, 306). This can be countered by 'increasing the directivity of the receiving antenna in the vertical plane so as to favour the waves arriving at one angle to the exclusion of the others' (Polkinghorn 1940, 306). Simply, this means that fading can be overcome if one of the multi-path waves can be isolated.

During the 1930s, Friis and Feldman developed the 'Multiple Unit Steerable Antenna' (MUSA) as a means to combat the limitations of short-wave radio transmissions. In 1937, when the results of their research were published, they described the MUSA as a:

'receiving system employing sharp vertical plane directivity, capable of being steered to meet the varying angles at which short radio waves arrive at a receiving location' (Friis and Feldman 1937, 841).

Prior to the work conducted by Friis and Feldman in the 1930s, point-to-point short-wave reception was achieved using a single rhombic antenna (Figure 5). The MUSA comprised a number of these antennae stretched out in a line orientated towards the transmitter. Each rhombic antenna was connected to the receiving apparatus by an individual coaxial cable. Although the antennae remain mechanically fixed, it was possible to adjust the apparatus so that the vertical angle of reception could be aimed at a particular component of the incoming short-wave transmissions (Bown 1937, 1132). 'The steering is done electrically with phase shifters in the receiving set. By taking several branch circuits in parallel from the antennae to different sets of adjusting and receiving apparatus the vertical signal components may be separated from each other' (Bown 1937, 1132).

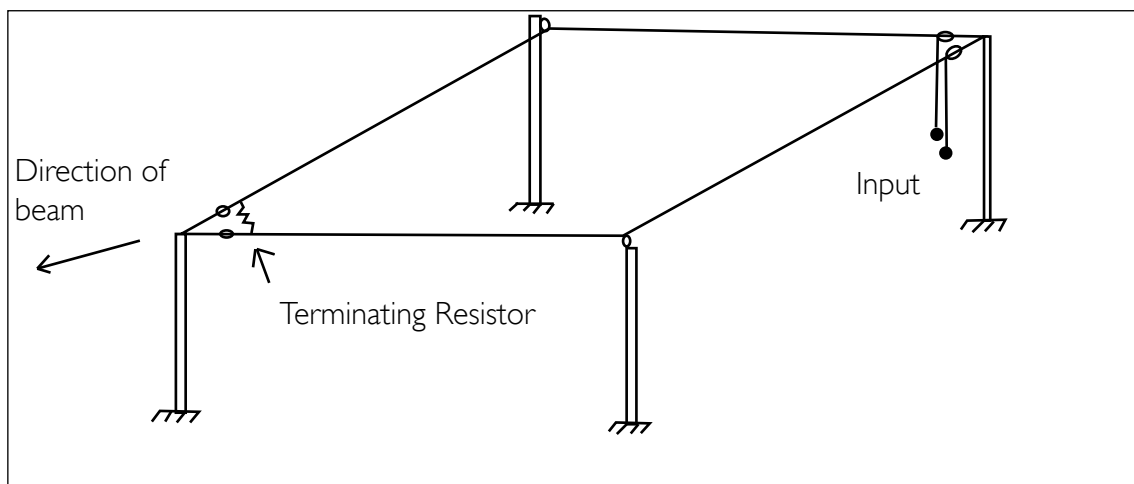
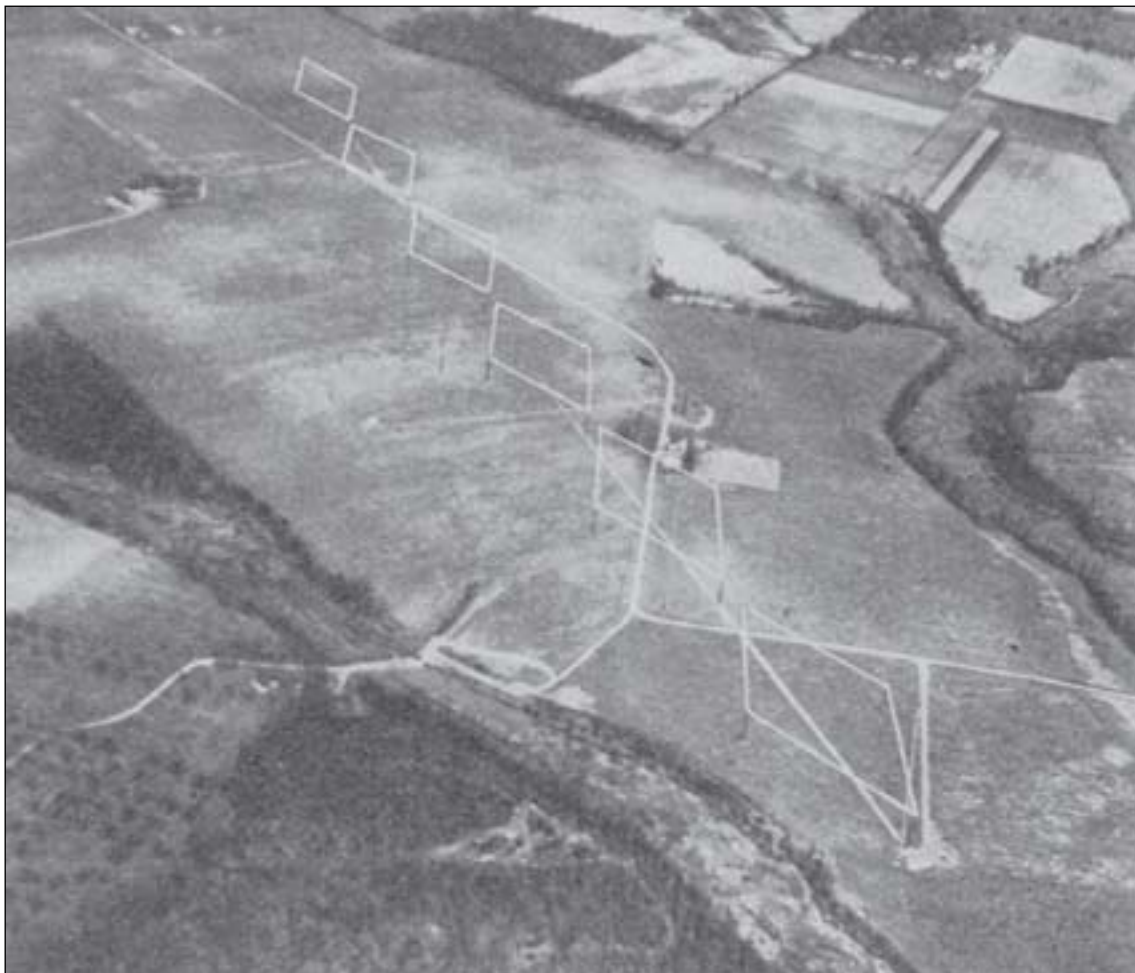


Figure 5: Rhombic antenna (after Page 1961, 478 © 1961 IEEE).

Each rhombic antenna of the MUSA picked up all the signals transmitted from America. The antennae were then programmed to receive the angle of reception of signal with the lowest signal-to-noise ratio. Identifying this angle occurred automatically every two seconds. Mumford (1945, 46) provides a detailed technical explanation for the way the antennae worked.

Friis and Feldman's experimental MUSA system was developed at the Bell Telephone Laboratories' field laboratory near Holmdel, New Jersey. This array consisted of six rhombic antenna extending over three quarters of a mile aligned with a transmitter in England (Figure 6). Compared to a simple receiver, the experimental MUSA showed an improvement in the signal-to-noise ratio of seven to eight decibels compared to the largest fixed antenna of the time (Friis and Feldman 1937, 915); an improvement against selective fading distortion; and an improvement against noise and distortion (Bown 1937, 1133). It was predicted that the construction of a MUSA three times larger than the one built at Holmdel would yield an additional signal-to-noise advantage of four to five



*Figure 6: View of the experimental MUSA system located at Holmdel, New Jersey (Friis and Feldman 1937, 845 © 1937 IEEE).*

decibels and perform more consistently (Friis and Feldman 1937, 915).

### The Post Office and the American Telegraph and Telephone Company (AT&T)

Between 1931 and the end of 1936, the average numbers of messages sent across the Transatlantic Telephone (TAT) had almost doubled (Figure 7) (BT Archives: POST 33/5313: 12/11/1936). To carry this traffic, four transatlantic radio channels were in operation by 1938 and capacity was also available for the initiation of a fifth channel. Three of these channels were transmitted over short-wave channels with only one long-wave channel in operation to America (BT Archives: POST 33/5313: 06/05/1938).

Date	Average Messages (per Business Day)
1931	56
1933	42
1935	46
1936 (last six months)	58
June 1936	69
July 1936	81
August 1936	71
September 1936	91
October 1936	102

Figure 7: Table showing the increase in messages sent over the TAT (BT Archives: POST 33/5313: 12/11/1936).

Scientists were predicting that during the 1940s there would be an increase in sun-spot activity. This increase in sun-spot activity was expected to cause serious disruption to the three transatlantic short-wave channels in operation. As 90% of conversation time over the TAT was of a commercial nature, the expected disruption would be of serious inconvenience to the public and to private business (BT Archives: POST 33/5313: 06/05/1938).

During the 1940s, scientists believed that sun-spots interfered with radio communications. Waves transmitted from a broadcasting antenna spread out in all directions. Those which travel directly over the surface of the earth are known as 'ground waves': ground waves can only travel a short distance. 'Sky waves' are transmissions which are broadcasted upwards. Eventually sky waves encountered a layer of ionised particles which reflected the radio waves back to earth. As long as this layer was stable, radio waves would return to earth relatively stable and regular. However, when the ionosphere was disturbed, reflection would be poor. Scientists had identified that the presence of sun-spots was directly linked to disturbance within the ionosphere (Stretson 1947, 209-210). During a period of high sun-spot activity, '[r]eflections are irregular and confused, and we fail to receive messages sent out from distant broadcasting stations' (Stretson 1947, 210).

Transferring all these channels to long-wave radio transmission was not a practical solution. The adverse effects on short-wave radio transmissions by sun-spot activity,



however, could be offset by employing the new MUSA antenna system (BT Archives: POST 33/5313: 06/05/1938). In 1936, the AT&T proposed the following programme of work: retention of the low frequency circuit from Rocky Point; postponement of the two proposed low frequency channels from Bradley, Maine; improvement of the high frequency circuits through the application of single sideband; improvement of transmitting antennae; and the use of MUSAs at receiving stations (BT Archives: POST 33/5313: 12/11/1936).

The Post Office agreed to the proposed programme: work on improving the short-wave channels should take priority over the construction of a second long-wave channel (BT Archives: POST 33/5313: 30/11/1936). '[F]or adequate improvement in receiving conditions, it is desirable to install at both ends of the [TAT] circuit a 'multiple unit steerable antenna [MUSA]' of the general type now used experimentally at Holmdel ... This type of antenna permits of [sic] receiving a wide band of frequencies, i.e. multiplex operation, and appears in this respect to be in line with the future trend of the art' (BT Archives: POST 33/5313: 12/06/1936). On the 17 August 1936, the Engineering Department of the Post Office commenced work to identify a suitable site for the construction of the MUSA (BT Archives: POST 33/5313: 17/08/1936).

### **Identifying a Suitable Site**

Whilst researching suitable sites for the construction of a MUSA, the Post Office's existing receiving station at Baldock was considered. However, this location was deemed unsuitable. It was decided that Baldock would be retained as the receiving stations for the 'Dominion Services' (BT Archives: TCB 2/102: 27/11/1936) and act as a stand-by station in case of MUSA failure (BT Archives: POST 33/4245 26/10/1937). As Baldock could not be used, discussions with American engineers led to an exercise to identify a suitable site in the south east of England (BT Archives: TCB 2/102: November 1936 WL/319).

It was desirable that the site chosen for the new station should have sufficient space to eventually accommodate two receiving antennae systems: one for horizontally polarised waves, the MUSA developed by Friis and Feldman, and the other for vertically polarised waves. The presence of both horizontal and vertical antennae systems would enable a technique known as polarisation diversity reception to be employed (BT Archives: TCB 2/102: November 1936 WL/319).

For the reception of low-angle vertically polarised waves, it was desirable that the site of the new station, and for three miles in front of the site, was highly conductive. Ideally, therefore, the selected site should be on low-lying flat ground adjacent to the sea. Locating the MUSA by the sea would ensure that the antenna system would be adjacent to highly conductive salt water (BT Archives: TCB 2/102: November 1936 WL/319).

The choice of suitable seaside locations in England was 'limited as there are few sites likely to meet the required conditions within 100 miles of London as the sea is in most cases unsuitably placed in relation to the land' (BT Archives: TCB 2/102: November 1936 WL/319). Coastal areas were also usually protected by a beach or sea wall owing to the high tidal range. The disturbance this would cause to the wave front would necessitate

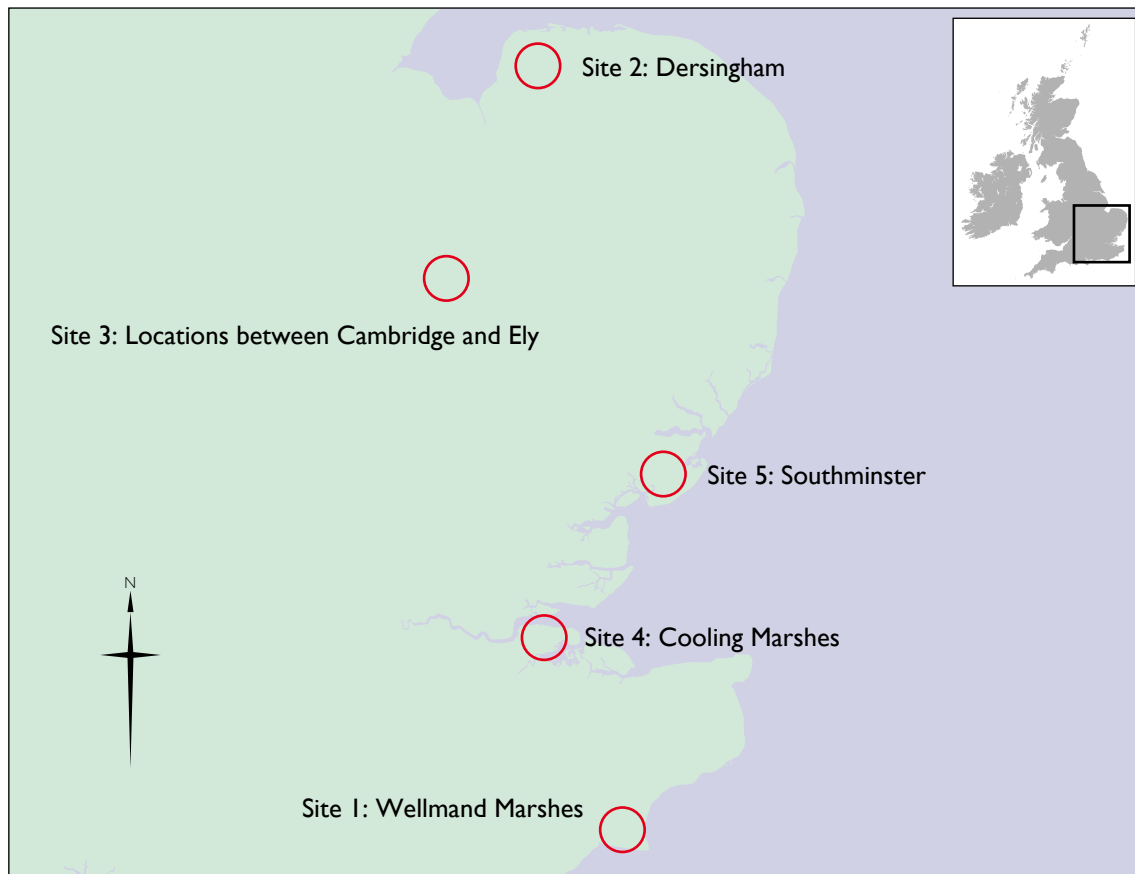


Figure 8: Map showing the sites identified as potentially suitable for the MUSA (after BT Archives: POST 33/5313).

locating the forward antenna some distance inland, consequently, losing the advantage of the sea (BT Archives: TCB 2/102: November 1936 WL/319).

Experiments conducted at Holmdel, although of a preliminary character by 1936, indicated that it might be possible to improve ground conductivity at a reasonable cost. This opened up the possibility of constructing a MUSA at an inland site. During Mr Friis's visit to England in 1936, discussions led to the expansion of the search area for a suitable location for the new transatlantic short-wave receiving station. By November 1936, the Post Office had identified five potential sites (Figure 8): 1) Welland Marshes, near Rye, Kent; 2) Dersingham, Norfolk on the eastern side of the Wash; 3) A number of possible sites between Cambridge and Ely; 4) Cooling Marshes near Cliffe-at-Hoo, Kent; and 5) East of Southminster, Essex (BT Archives: TCB 2/102: November 1936 WL/319).

With the exception of the land between Cambridge and Ely, all the potential sites were located on poor agricultural land which was mainly used for grazing. Site One, Welland Marshes, was an inland site which could accommodate a two mile antenna system with a forward clearance of approximately two miles to the nearest road. Located only 56 miles from London, the ground was of low conductivity and the presence of private aeroplanes might have proved a source of interference. The site was deemed suitable, but not ideal (BT Archives: TCB 2/102: November 1936 WL/319).

Site Two, Dersingham, was located in a two mile stretch of land defined by a railway and the eastern shore of the Wash. Due to the presence of a shingle dyke which stretched inland, an antenna array located here would have to be set back from the shore by approximately half a mile. This would leave only three and a half miles for the full length of the MUSA which was deemed to be insufficient (BT Archives: TCB 2/102: November 1936 WL/319).

Half a mile to the north of the proposed site at Dersingham, was the bungalow town of Snettisham. The growth of this settlement had the potential to disrupt a receiving system as a result of an increase in electrical disturbance from motor car ignitions. Potentially, the site at Dersingham would be suitable for a reduced MUSA array. Although other possible sites were identified nearby, due to the distance to London other options were to be explored first (BT Archives: TCB 2/102: November 1936 WL/319).

Representatives of the Post Office could not examine potential sites between Cambridge and Ely in detail; 'since the land was under cultivation, it was impossible to proceed over it without some explanation to the owners' (BT Archives: TCB 2/102: November 1936 WL/319). One potential site was identified from the main road. Consideration, however, was deferred until sites to the south had been examined (BT Archives: TCB 2/102: November 1936 WL/319).

Cooling Marshes, Site Four, consisted of an area of flat land on the south bank of the River Thames. Located only 27 miles from London, the site offered ample space for the two mile antenna system with a three mile forward clearance to the centre of the river. At the time, the only occupation of the site was a disused explosives factory approximately two miles from the position of the forward antenna. The site, acquired by the Port of London Authority prior to 1936, was not identified for development (BT Archives: TCB 2/102: November 1936 WL/319).

On initial inspection, it was deemed that there should not be more than average background electrical noise present at Cooling as there was no power plant within several miles. Tests were planned to identify whether ships' wireless installations and ignition systems on motor boats might cause interference. However, little wireless traffic was experienced in this reach of the Thames due to the difficulties of working with the North Foreland coast station. Testing of wireless equipment might occur in Tilbury docks and Sheerness. Tilbury, however, was seven miles from the marsh and about 40° off the line of reception and Sheerness seven miles behind the alignment of the antennae. Motor boat activity, which would be screened by the river bank (sea wall), was limited except at weekends. Consequently, background interference was expected to be minimal (BT Archives: TCB 2/102: November 1936 WL/319).

Site Five, Southminster, was deemed unsuitable as access was difficult and there was an Air Ministry station in the vicinity. Of all the potential sites examined, Cooling appeared to be the most suitable. If the site proved unobtainable, the second choice was to locate the MUSA on the fens between Cambridge and Ely (BT Archives: TCB 2/102: November 1936 WL/319).

## Purchasing Land at Cooling

With a potential site identified, £32,000 was included in the Post Office's annual estimates for the period 1937/1938 to cover the capital cost of the new station. This included the cost of the antennae, feeder lines, receivers and power supplies, but did not cover the cost of the land, buildings and roads which were estimated to be in the order of £28,000 (BT Archives: TCB 2/102: 20/11/1936). The building, including pilings, alone was roughly estimated at £16,200 (BT Archives: TCB 2/102: 14/01/1937). Initially the intention was to rent the land for the erection of a temporary building and to obtain wayleaves for the masts and feeder lines (BT Archives: TCB 2/102: 20/11/1936).

On the 8 April 1937, Mr KHC Badger, of the Directorate of Lands and Accommodation of HM Office of Works, was requested by Mr AJ Gill, of the Post Office's Engineering Department, to set in motion negotiations for the acquisition of the site at Cooling. Gill personally felt that it would be a safer option to purchase the land outright, dependent on reasonable terms. Although the tests which had been conducted at Cooling were so far inconclusive, the Post Office could not afford to delay opening negotiations. Gill was concerned that they might run into the danger of not being able to access the site by the time they were ready to commence construction (BT Archives: TCB 2/102: 08/04/1937).

By the 24 June 1937, tests at Cooling indicated that as far as technical requirements were concerned, the site would be suitable for the MUSA. However, during the 10 days leading up to the 24 June 1937, the Engineering Department learned that proposed activities by the Air Ministry in the Rochester area might interfere with a MUSA located at Cooling. Further tests were commissioned to verify whether the expected interference would be undesirable (BT Archives: TCB 2/102: 24/06/1937).

These tests revealed that interference from present Air Ministry stations would be unlikely to affect the proposed MUSA. However, any station built in closer proximity to Cooling, or if the wave lengths used by the Air Ministry were shortened, interference would be expected. If the Air Ministry were willing to observe certain restrictions relating to the location of further stations and of the wave lengths used, interference could be kept to a minimum. However, if assurance was not forthcoming, negotiations to acquire up to two sites in the west of England, instead of the south-east, should be initiated (BT Archives: TCB 2/102: 23/07/1937).

By the 4 August 1937 the Air Ministry stated 'that in view of the important issues involved, they are not in a position, in the light of present knowledge, to agree to these restrictions' (BT Archives: TCB 2/102: 09/08/1937). The Post Office decided that negotiations should continue for the site at Cooling Marshes whilst enquiries were made about acquiring alternative sites (BT Archives: TCB 2/102: 09/08/1937).

These continuing discussions, between the Post Office and technical representatives of the Air Ministry, led to the Ministry agreeing to certain restrictions on future activity in the Cooling area prior to 3 September 1937. These restrictions would render interference as negligible. Whilst awaiting formal confirmation, Badger was requested to proceed with negotiations (BT Archives: TCB 2/102: 03/09/1937). Due to the uncertainty so far encountered, the Superintending Estate Surveyor requested that the Post Office

reimburse the Vendors expenses up to £150 if the Post Office withdrew from the scheme (BT Archives: TCB 2/I02: 27/08/1937).

Ideally, the Post Office hoped to acquire the land for the apparatus building either as a freehold or on a long lease (BT Archives: TCB 2/I02: 27/08/1937). The structure, located either at the centre or at one end of the array, would be approximately 60ft x 60ft (18.29m x 18.29m) with a number of smaller buildings in close proximity. Wayleaves would have to be obtained in order to access the site and for the provision of power and telephone circuits. Any agreement signed by the Post Office also had to involve the right to clear the land of trees, shrubs and tall hedges (BT Archives: TCB 2/I02: 09/08/1937).

Enquires identified 13 landowners who would have to participate in the Post Office's negotiations (BT Archives: TCB 2/I02: 27/08/1937). Some of the land owners were unwilling to sell as they felt this would prevent access to parts of their property, especially if the land was fenced off and under sole control of the Post Office. The Post Office, therefore, tasked their solicitor to draw up a short draft lease which could be modified, when necessary, to individual requirements. This lease gave the owners and tenants full rights of use (BT Archives: TCB 2/I02: 28/09/1937). As the Post Office wanted to obtain possession of the site by Easter 1938, they wanted to keep negotiations as simple as possible (BT Archives: TCB 2/I02: 26/10/1937).

On the 19 October 1937, a meeting was held in connection to the ongoing negotiations. Representatives from the Post Office's Personnel Department, Engineering Department, Solicitor's Department, the Office of Works, as well as Mr R Cobb (representing eight of the thirteen landowners), a representative of the Ecclesiastical Commission, and several landowners, were present (BT Archives: TCB 2/I02: 26/10/1937).

At this meeting Commander BV Sturdee, of the Post Office's Personnel Department, informed the meeting that the proposed receiving station was of 'national importance'. Those in attendance were also informed of the possibility of the Post Office constructing a second antenna array in parallel to the first at a future date. Although fencing would be erected around the main building, landowners' fears of the Post Office fencing the whole site were unfounded. The Post Office only intended to protect the 60ft (18.29m) antennae with standard cattle guards (BT Archives: TCB 2/I02: 26/10/1937).

Cobb argued that the proposal to take this strip of land would divide properties and effectively stop the owners from developing or selling the whole of their land (BT Archives: TCB 2/I02: 26/10/1937). The Chairman subsequently informed Cobb that 'little severance would result if the strip of land was rented' (BT Archives: TCB 2/I02: 26/10/1937). At this point the official representatives withdrew as Cobb had been working on the assumption that the Post Office wished to purchase the land. On resumption, Cobb was informed that the Post Office could exercise their powers to compel the owners to lease the properties; however, they would prefer to negotiate. The Chairman told the meeting that the Post Office desired to rent the whole area at a flat-rate instead of paying a rent for each pole erected (BT Archives: TCB 2/I02: 26/10/1937).

Cobb indicated that his clients who were willing to sell wanted £40 per acre while those

willing to lease wanted 40s per acre per annum. The land would then be leased back to the tenants for grazing at 15s per acre. Therefore, the Post Office was expected to pay 25s per acre per annum for the privilege of erecting a few poles (BT Archives: TCB 2/102: 26/10/1937). Representatives attempted to justify the rent 'by referring to the possible use of the land for clay digging or for a Rifle Range and to the difficulties that might be caused by the severance of their land for as long as 50 years' (BT Archives: TCB 2/102: 26/10/1937).

At the close of the meeting, Mr Mugeridge, the owner of the land where the apparatus building was to be erected, stated that he preferred to sell his land, but as he did not want to obstruct proceedings, he was also prepared to lease. Mugeridge also agreed to possession of his land being taken prior to the completion of the legal negotiations (BT Archives: TCB 2/102: 26/10/1937). To ensure that the building was ready for the equipment to be fitted by August 1938, the Post Office wanted to take control of the site by February 1938 (BT Archives: TCB 2/102: 29/12/1937).

Following this meeting, the landowners presented two proposals to the Post Office. Either the owners would grant licences, at a rate of 10s per acre per year, for the erection of the masts for a period of 50 years (Scheme One); or the Post Office could purchase the land. However, some landowners would only sell all their land in the marsh as they felt the value of the remainder would be permanently reduced (Scheme Two). It was deemed necessary that the Post Office purchased the land at the eastern end of the array for the construction of the apparatus building (BT Archives: TCB 2/102: 27/10/1937).

It was estimated that 300 acres of land were required for the construction of the new receiving station and antenna array. Scheme One was budgeted at £4,100 (purchase of 100 acres at £40 an acre = £4,000 and license of 200 acres at 10s an acre = £100 per annum) whilst Scheme Two was estimated at £20,000 (purchase of 500 acres, allowing for land owners who refused to sell a portion of the land, at £40 an acre) (BT Archives: TCB 2/102: 27/10/1937).

The Post Office felt that Scheme Two was the only way to provide absolute security of tenure. However, this scheme might result in severe delays as landowners not willing to sell might stall negotiations. Negotiations could, however, be concluded within three months of February 1938, if the Post Office erected the antenna system under consents in accordance with the Telegraph Acts (BT Archives: TCB 2/102: 26/11/1937). By the 4 January 1938, the Post Office decided to pay 10s for the erection of each mast and 2s 6d for each furlong of underground pipes (BT Archives: TCB 2/102: Extract from a minute of Telecommunications Department, dated 4th January).

Negotiations for the purchase of Mugeridge's land were still ongoing in January 1938, after almost one year. On the 15 January, Mugeridge made the following demands: the sum of £100 per acre for three acres; £350 towards the cost of the road he had constructed and £25 per annum for its upkeep; the right to use the road constructed to the apparatus building paid for by the Post Office; the right to graze the land during construction; the drainage and water supply were not to be interfered with; all fencing, bridges, and gates to be maintained; the bore-hole dug by the Post Office was to be left open so that

he could make use of this to obtain water; and all legal and surveyor costs to be paid. The Post Office estimated that the total cost of Mugeridge's offer would be £735 (BT Archives: TCB 2/102: 17/01/1938).

Initially, it was intended that the Post Office would purchase 60 acres of land for the construction of the building (BT Archives: TCB 2/102: 27/09/1938). 'It is, therefore, somewhat of a disappointment to the Vendor that only three acres of his land is being purchased, and having regard to this, the final negotiations with the Vendor have been a trifle difficult' (BT Archives: TCB 2/102: 17/01/1938). It was, therefore, recommended to accept the offer outright with no attempt at further negotiations (BT Archives: TCB 2/102: 17/01/1938). By the 20 January, Treasury approval had been received for the purchase of the site on Mugeridge's terms and conditions (BT Archives: TCB 2/102: 20/01/1938). Confirmation was received on 21 January (BT Archives: TCB 2/102: 21/01/1938).

Negotiations associated with the supply of water to the apparatus building were still ongoing in February 1938. The terms offered to the Post Office were that they would have to pay one third of the initial cost, approximately £321 19s 7d, and one third of the maintenance cost of the 1½ inch pipe from the Higham and Hundred of Hoo Company's main to the Mugeridge's meter. The Post Office would also have to pay half the maintenance cost of the 1¼ inch pipe from the main to the meter where they took their supply. Mugeridge insisted that the new mains pipe from his farm to the apparatus building should be 1 inch bore and installed and maintained by the Post Office (BT Archives: TCB 2/102: 07/02/1938).

On 30 March 1938, the Solicitor's Department wrote to the Accountant General's Department outlining the following accounts which required payment:

1) Outstanding balance (£100 had already been paid as a deposit)	£200 0s 0d
2) Contribution towards the cost of the road	£350 0s 0d
3) Compensation for grazing	£35 0s 0d
4) Connection of water supply payable to Mr Mugeridge	£53 10s 0d
5) Connection of water supply payable to Messrs Edmonds	£53 10s 0d
6) The Vendor's Solicitors' costs	£26 5s 0d
7) Vendor's Solicitors' costs in connection with the water supply	£10 10s 0d
8) Stamp duty	£0 15s 0d
9) Vendor's Surveyors' costs	£26 5s 0d

(BT Archives: TCB 2/102: 30/03/1938)

The purchase of the land for the apparatus building was completed on the 1 April 1938 (BT Archives: TCB 2/102: 05/04/1938). In 1947, it was estimated that the total cost of the receiving station at Cooling was approximately £100,000 (BT Archives: POST 33/5313 08/04/1947).

## The Apparatus Building

Initially, it was intended that the building to house the receiving apparatus would be a temporary structure. This was because, at the time, the requirements of the structure were still uncertain and the Post Office was working to a tight timeframe. Once the temporary structure was erected, work would begin on the permanent building and the equipment would be transferred on completion. However, the decision to construct the apparatus building at the eastern end of the array necessitated using a heavier gauge

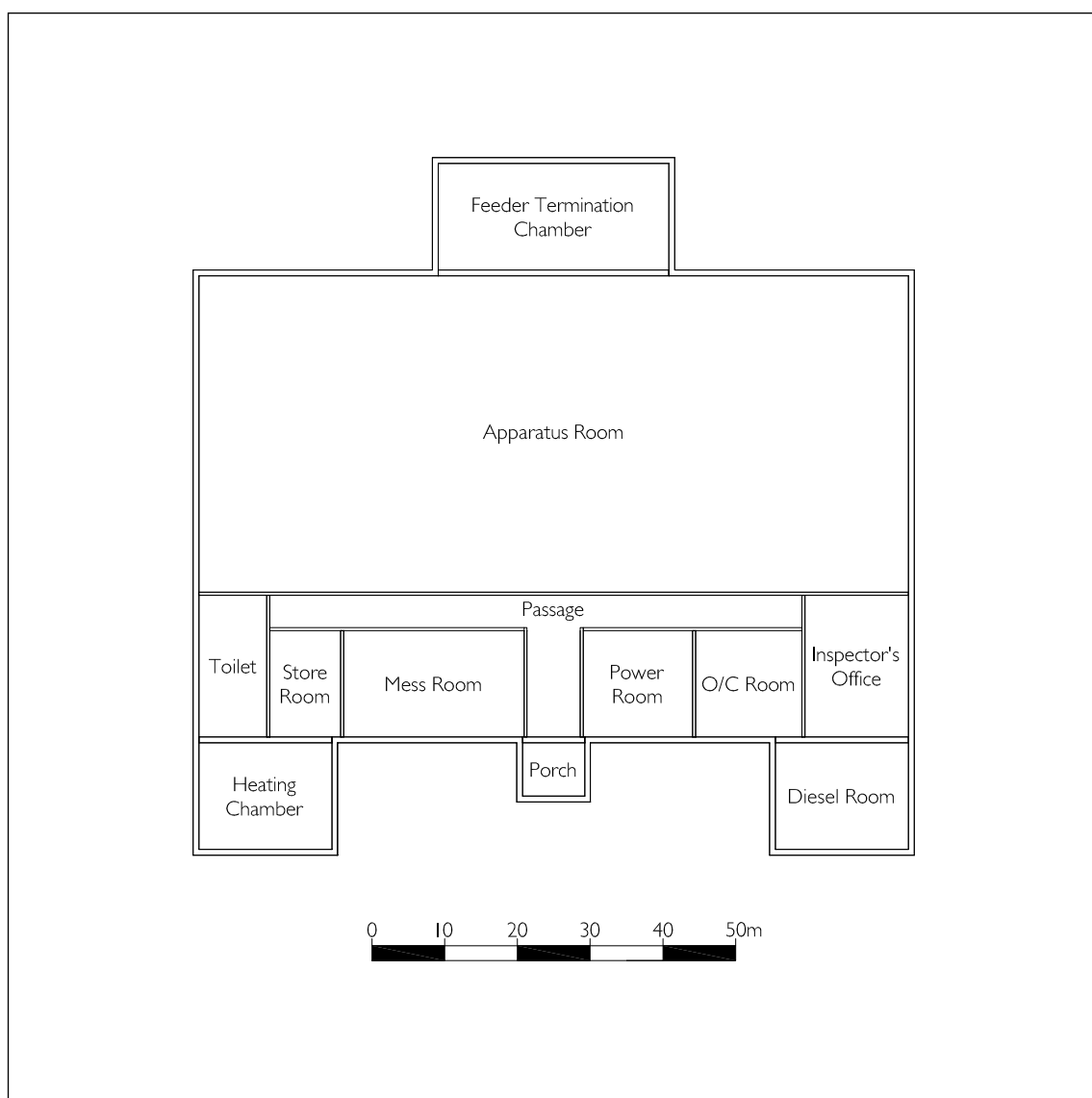


Figure 9: Proposed layout of the apparatus building (after BT Archives: POST 33/5313 Cooling Receiving Station Proposed Layout of Building DRG WL.20.720)



of copper feeder tubes, probably due to the greater distances involved. If these were installed in a temporary building, service would be disrupted for several weeks as they were transferred (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester).

Standard building types 'such as Type D or E U.A.X. or of adopting an existing building exactly as installed at Baldock or any other receiving station, has been thoroughly examined. This examination has shown that the peculiar disposition of the equipment which will be necessary at the Cooling station does not permit of any such building being utilised' (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester).

Working drawings of the proposed apparatus building were completed by the 17 January 1938 (Figure 9) and were sent out to tender. The Post Office aimed to collect responses by the 29th January so that a decision could be made by the 5 February 1938 (BT Archives: TCB 2/102: 17/01/1938). The internal layout on the working drawings is very similar to that surveyed; however, the proposed roof line is different from that eventually built (Figure 10).



*Figure 10: Cooling Radio Station apparatus building (courtesy of Frank Turner).*

The building was designed with the intention that it could be extended at a future date. Either the space occupied by offices could be cleared and new office accommodation constructed elsewhere; or the building could be extended to the north (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester). Material used in the construction of the partition walls

was expected to be lightweight so that they could be removed with the minimum of cost and interference (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester). Structural evidence indicates that during construction of the apparatus building, consideration of future expansion was taken into account (see Apparatus Building Survey). Purposefully left gaps in the reinforced concrete were bricked up enabling the expansion of the building outwards, or enabling an increase in internal cables, with the minimum of cost and disruption.

The marsh on which they constructed the apparatus building consisted of a surface layer of 2ft (0.61m) of medium hard clay beneath which was extremely soft mud to a depth of approximately 90ft (27.43m). It was, therefore, essential to sink 150 concrete piles 80ft (24.38m) into the marsh to support the weight of the building (BT Archives: Cooling Radio Station Folder: 14/09/1938). Requirements of the apparatus building included:

'No cable chases are required in the floor and there are no special requirements regarding windows or doors, except that operating staff will be permanently employed at the station. The building must have a clear height of at least 12 feet [3.66m] in the apparatus room and wooden roof trusses are preferable. Roof supporting piers should be kept at a minimum in the apparatus room' (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester).

Heating of the building would be achieved through the installation of a hot water system (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester). To prevent vibrations from the generator affecting the apparatus, the floor of the diesel (generator) room was to be insulated from the main building. On the outside of the feeder tube termination chamber, the feeder tube inlets were to be hooded within earthenware or other approved material. Internally, all doors were to be half glazed (BT Archives: POST 33/5313: Cooling Receiving Station proposed layout of Building DRG.WL.20.720).

Plans for the apparatus building provided sufficient space to accommodate 'six [transatlantic short-wave radio] channels initially, and the opportunity has been taken to design the layout of the apparatus to be the most suitable for this number of circuits to meet the immediate demands' (BT Archives: POST 33/5313 18/11/1937).

## Construction

Although the precise start date of building work at Cooling is unknown, Humphrey Jennings' film directed in 1938, on behalf of the GPO Film Unit, entitled 'Speaking from America', shows construction in progress (Jennings 1938). The Post Office hoped that the brick feeder termination chamber (Figure 11) and the concrete floor would be completed by August 1938. Completion of the terminating chamber was vitally important as the laying of the feeder tubes could only be conducted in the summer as the marshes became waterlogged in wet weather (Figure 12) (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester).



*Figure 11: Feeder termination chamber under construction (still from Jennings 1938 © Royal Mail Group Ltd 2011, courtesy of The British Postal Museum & Archive).*

If these two components could be completed before the end of the summer of 1938, a temporary wooden structure could be erected over the apparatus. This structure would be supported on the concrete floor and would be of slightly smaller dimensions than the proposed apparatus building. Construction of the permanent building could then go on around this wooden building (BT Archives: POST 33/5313: Memorandum: Building required for the new Receiving Station at Cooling Marshes, Rochester).



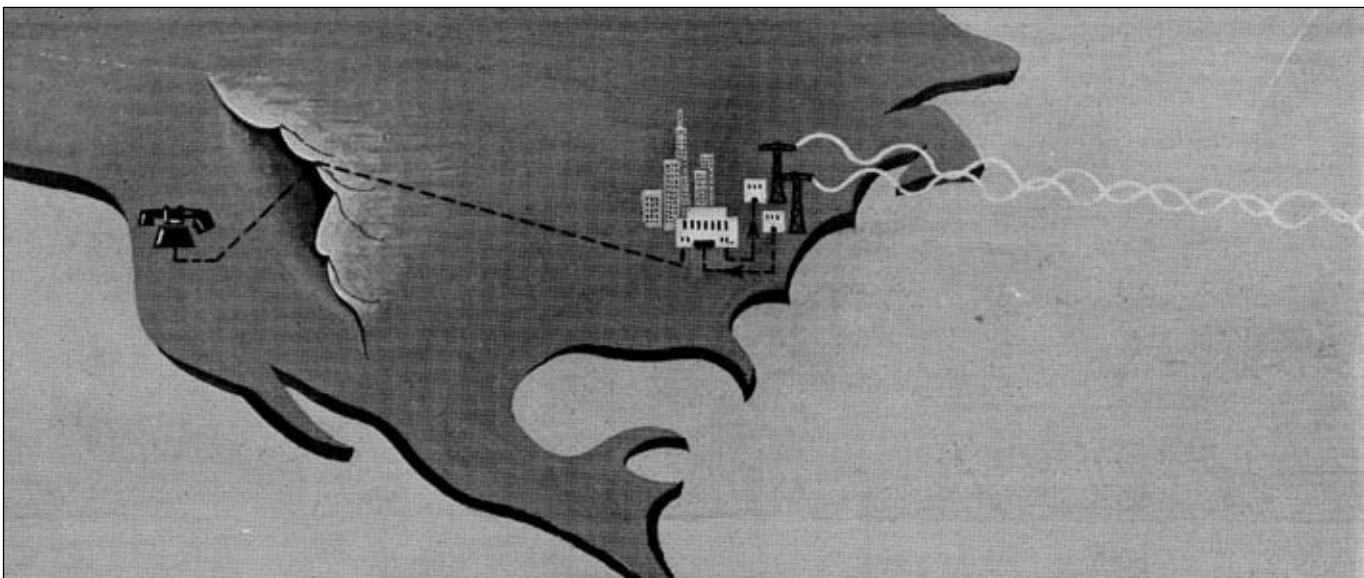
*Figure 12: Laying the feeder tubes (still from Jennings 1938 © Royal Mail Group Ltd 2011, courtesy of The British Postal Museum & Archive).*



*Figure 13: Photograph showing one of the pair of gates which the Post Office erected at a cost of £66 (© English Heritage).*

Since the road which led from Mugeridge's farm to the Receiving Station had been completed, Mugeridge had been inconvenienced by through-traffic. Those using the road were generally sightseers who had seen the new receiving station mentioned in the press (BT Archives: TCB 2/102: 20/10/1938). Consequently, Mugeridge requested that iron gates with side piers should be erected by the Post Office (BT Archives: TCB 2/102: August 1938 51522/38).

Initially, erection of the gate was objected to by the Engineering Department: once the station was operational, staff would be using the road constantly both day and night. Instead it was suggested that a notice board be erected on a trial basis (BT Archives: TCB 2/102: 16/08/1938). Mugeridge, however, deemed this to be insufficient (BT Archives: TCB 2/102: 26/10/1938). Due to the Mugeridge's good-will, helpful attitude,



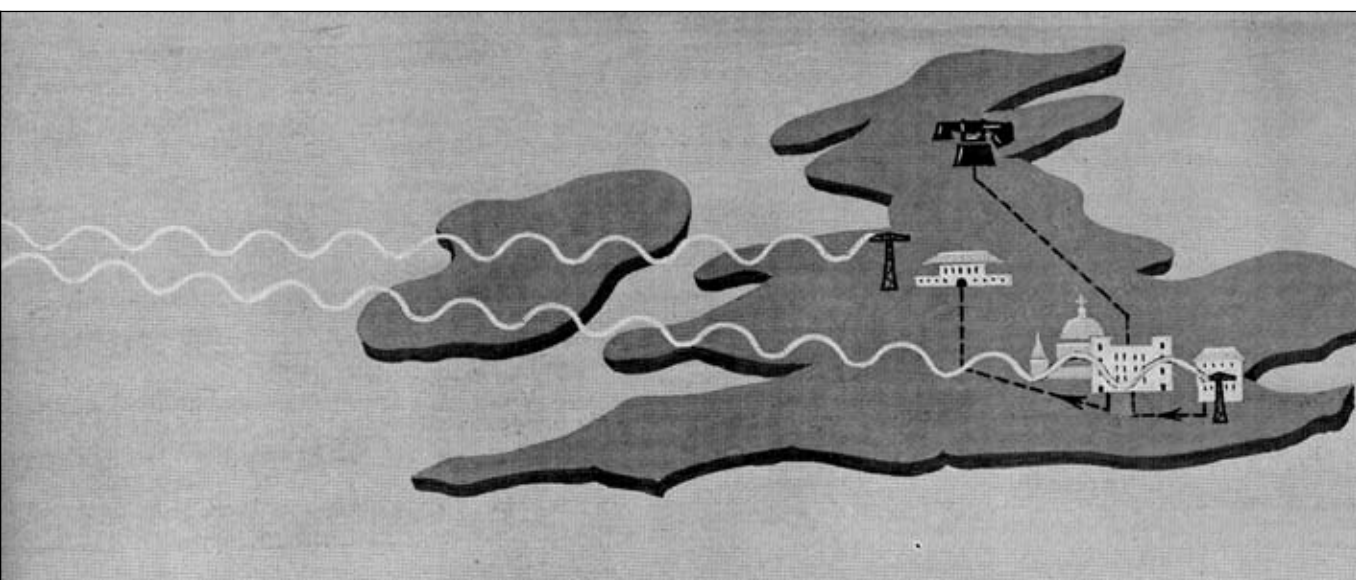
*Figure 14: Transatlantic telephone link during the Second World War. Although the stations are not marked, they are believed to represent Cooling, Rugby, Lawrenceville, and Manahawkin (Hay 1946, 56-7).*

and assistance, Mr Bristow, a Senior Architect, felt that the Post Office was indebted and recommended that approval for the gate should be given (BT Archives: TCB 2/102: 26/10/1938). On the 29 October 1938, the Post Office agreed to erect the gates at an estimated cost of £66 (Figure 13) (BT Archives: TCB 2/102: 29/10/1938).

On the 4 October 1938, the solicitors Messrs Arnold Tuff and Grimwade contacted the Post Office on behalf on Mugeridge. Under the conditions of the sale of the land, Mugeridge was paid £35 compensation for interference with grazing of Marsh no. 56. Mugeridge claimed that during construction he was also unable to graze the adjoining marsh (No. 57) owing to it being used as an entry route and dump by the contractors (BT Archives: TCB 2/102: 04/10/1938). The sum of £25 compensation for the loss of grazing and £10 to repair the damage was demanded (BT Archives: TCB 2/102: 24/01/1939). The Post Office was 'willing to consider (without prejudice) the question of paying ... some reasonable compensation for any interference there may have been with his grazing right' (BT Archives: TCB 2/102: 22/10/1938).

After consideration, the Post Office admitted that stores and lorries were placed on Marsh no. 57 (BT Archives: TCB 2/102: 18/10/1938). On the 3 March 1939 the Post Office requested that a warrant for £25 should be made payable to Mr Fred Mugeridge as compensation (BT Archives: TCB 2/102: 03/03/1939).

For an improvement in radio reception, a MUSA had to be installed at both ends of the circuit. In early 1938, it was expected that the MUSA at Manahawkin, New Jersey, would be completed in the spring or summer of 1939. Cooling Radio Station was completed prior to September 1939. With the outbreak of the Second World War, testing of the circuit was suspended. Testing recommenced towards the end of 1941 and the equipment came into service on the 1 July 1942. With this, the quality of the reception over transatlantic radio telephone increased (Mumford, 1947: 25).



## Technical Details

To achieve the full benefits which a MUSA offered, it was essential that a MUSA was constructed at either end of the transatlantic short-wave circuit (Figure 14). Cooling's sister station was constructed at Manahawkin, New Jersey (Bray 2002, 80). Short-wave radio waves would be transmitted from Rugby, England (Booth 1949, 85-6) and be received by the MUSA at Manahawkin (Bray 2002, 80). The response would be transmitted from Lawrenceville, New Jersey (Booth 1949, 85) and be received at Cooling.



*Figure 15: Image looking along the MUSA during construction. In the distance, one can see the faint outline of the telegraph poles used to construct the rhombic antennae (still from Jennings 1938 © Royal Mail Group Ltd 2011, courtesy of The British Postal Museum & Archive).*

The antenna array at Cooling comprised of 16 rhombic antennae spaced over two miles pointing towards the transmitter in Lawrenceville (Figure 15). Each antenna was 60ft (18.29m) high with sides of 315ft (96.01m) and internal angles of 140° (Figure 16). The centre of each unit was separated by 656ft (199.95m) (Booth 1949, 86).

The transmission lines from the antennae were laid side by side at the bottom of a trench whose average depth was 2ft 3in (0.69m). These lines were of the concentric tube type and consisted of a core (diameter 5/8 inch [0.02m]) and sheath (diameter 2 inch [0.05m]) made from high-grade copper tubing. The tubing was supplied in lengths which varied from 16ft (4.88m) to 20ft (6.10m) and required approximately 4,500 joins in both the core and sheath. As it was essential that these joints were water-tight, the standard jointing-sleeve was modified and an additional radial flange was used (Hall et. al 1940, 138).

Due to the seasonal temperature change, it was thought that there might be differential

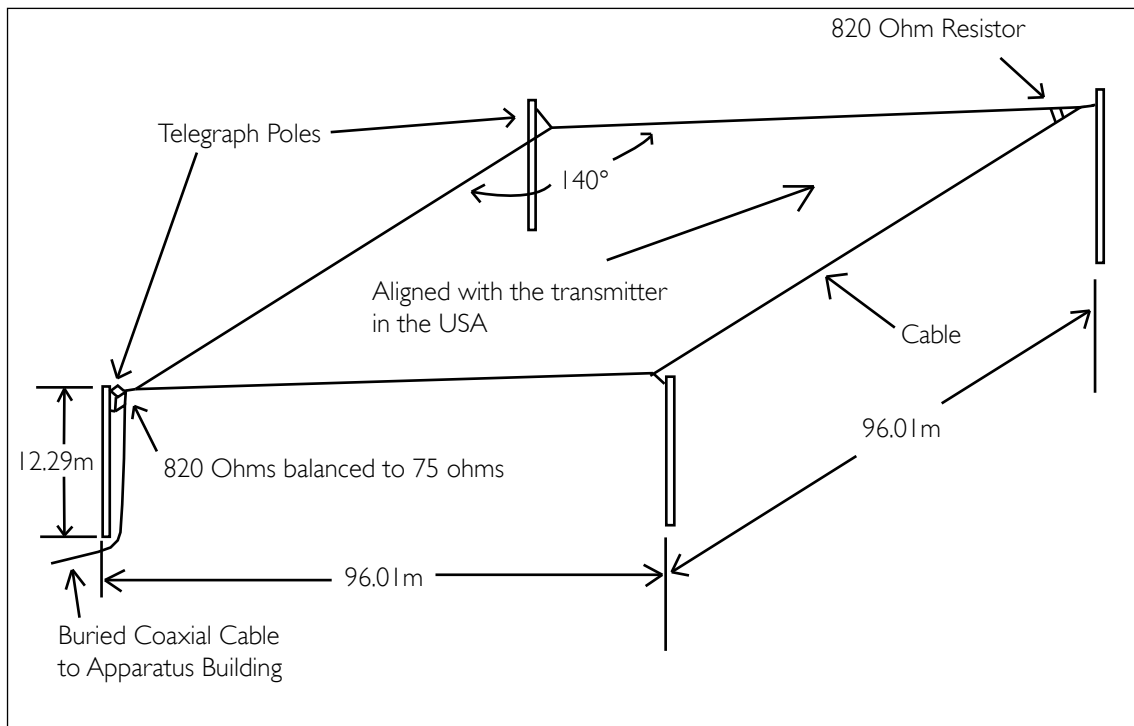


Figure 16: Diagram showing the design of the rhombic antenna at Cooling (after Booth 1949, 86).

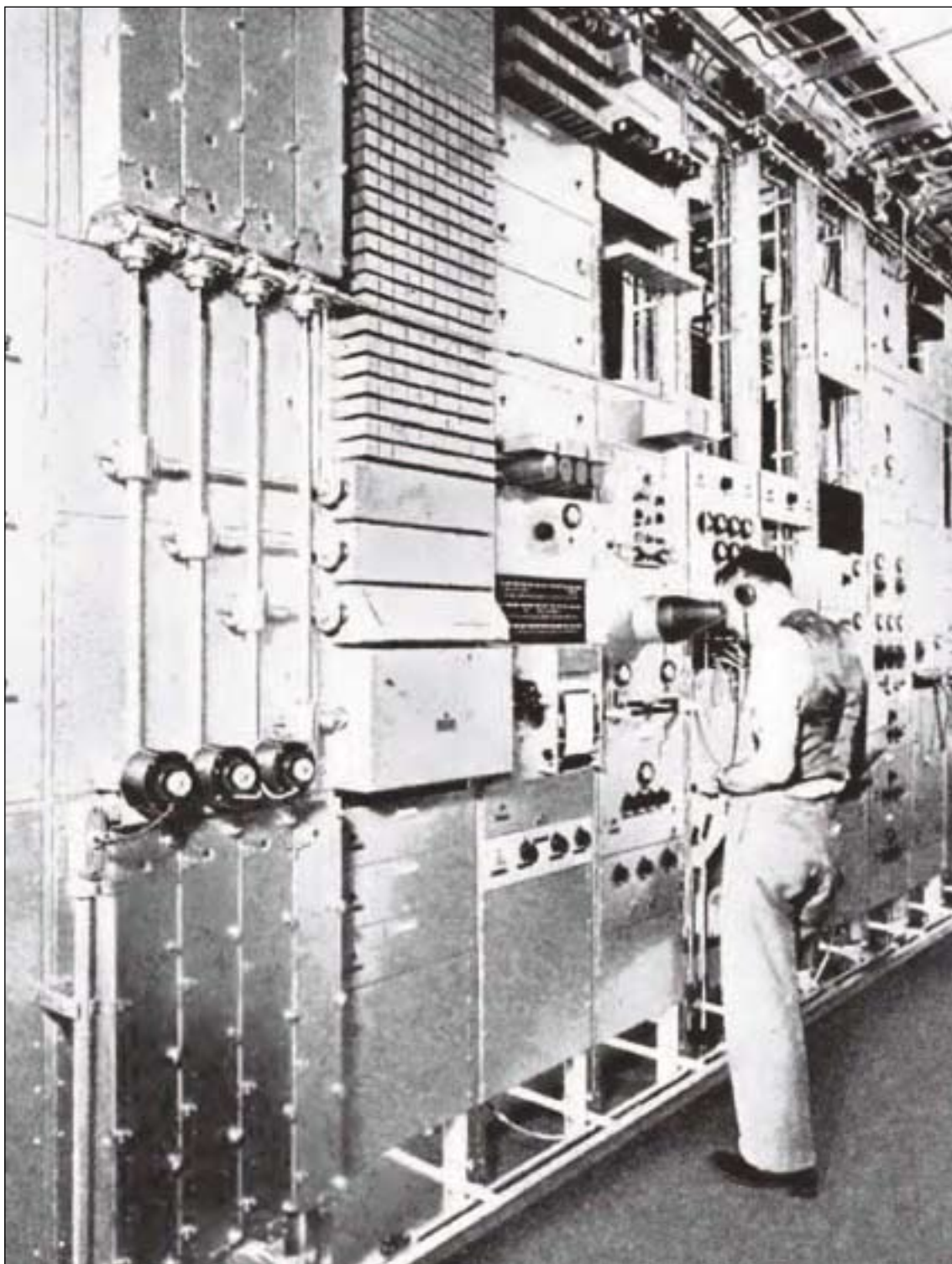
expansion rates between the core and the sheath. This was solved by the use of three-legged spacing insulators constructed from high-grade ceramic material fixed to the core at 2ft (0.61m) intervals (Figure 17). The three arms of the insulator were slotted into cuts made into the sheathing whilst a copper or silver deposit on the bore permitted it to be soldered onto the copper core (Hall et. al 1940, 138).



Figure 17: Three-legged spacing insulator (still from Jennings 1938 © Royal Mail Group Ltd 2011, courtesy of The British Postal Museum & Archive).

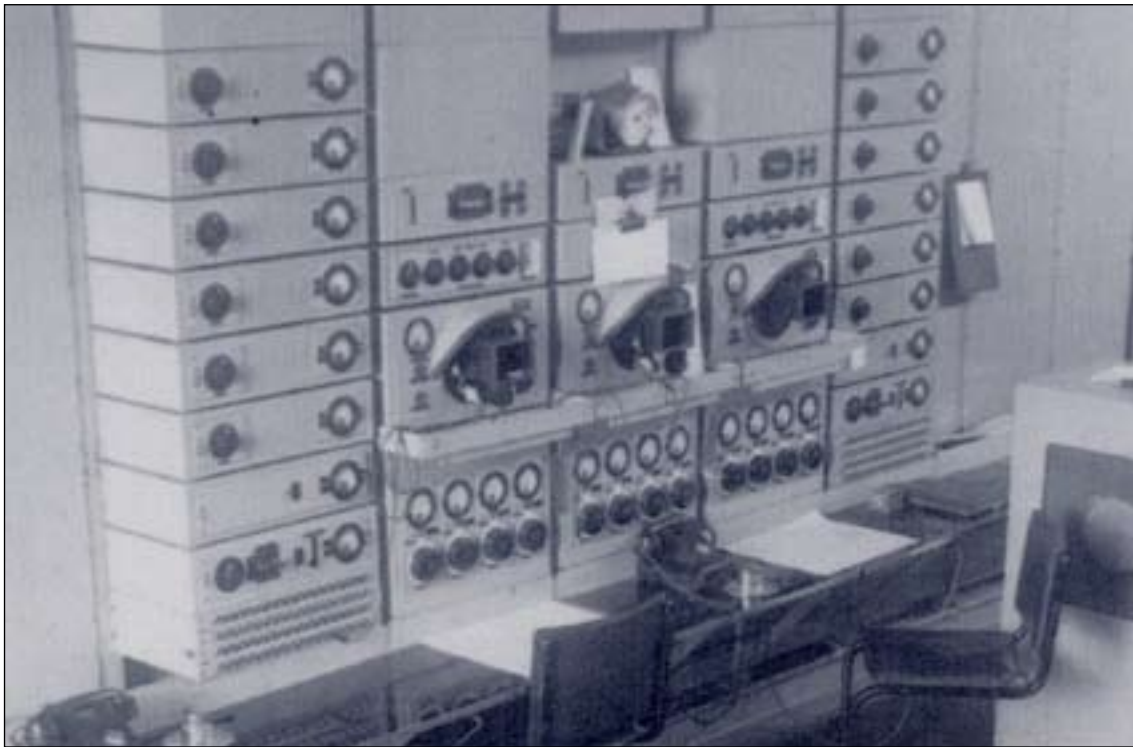


Once the electrical currents passed through the transmission line to the receiver, the inputs from the 16 antennae were amplified, their frequency changed, and the phase corrected (Figure 18) to compensate for the time delays associated with the different transmission paths (Booth 1949, 86).



*Figure 18: MUSA phase shifter at Manahawkin (Polkinghorn 1940, 320 © 1940 IEEE).*





*Figure 19: Equipment at Cooling Radio Station (courtesy of Frank Turner).*

Initially, it was planned that Cooling would operate six receivers; however, only two were installed (BT Archives: Cooling Radio Station Folder: 14/09/1938). As twin-channel operation was in use, a total of four radiotelephone channels were in operation through the Cooling circuit (Booth 1949, 87). The receiving equipment at Cooling utilised 1,079 valves (Angwin 1950, 442) and occupied 60 10ft 6in (2.08m) repeater racks with front and back mounting (Figure 19, Figure 20 and Figure 21; Booth 1949, 86). Each receiver at Cooling operated on any of five frequencies in the range 4,000 to 22,000kc/s (kilocycles per second) (Booth 1949, 87). It was expected that when the station was in full operation, a total of 12 members of staff would be required to maintain the apparatus (BT Archives: POST 33/5313: 06/05/1938 New Transatlantic Receiving Station at Cooling, Rochester).

As well as operating the two MUSA receivers, Cooling also operated two 'normal' receivers: one of these was for traffic, whilst the other was for monitoring (Hancock pers comm). Although the date these 'normal' receivers were installed is unknown, two large rhombic antennae have been mapped from historic aerial photographs from 1961 (Figure 43) (NMR RAF/58/4137 F96 F43 64 9-FEB-1961) and may be related.

Originally it was intended to provide a second MUSA system at Cooling to be used on the Commonwealth Services; however, this was postponed due to the outbreak of the war. However, on the 8 April 1947, it was stated that this was soon to be put into hand (BT Archives: POST 33/5313: 08/04/1947). No evidence for this MUSA has been found.

When identifying a suitable location for the construction of the MUSA, space for the development of further antenna arrays was taken into consideration. These antenna

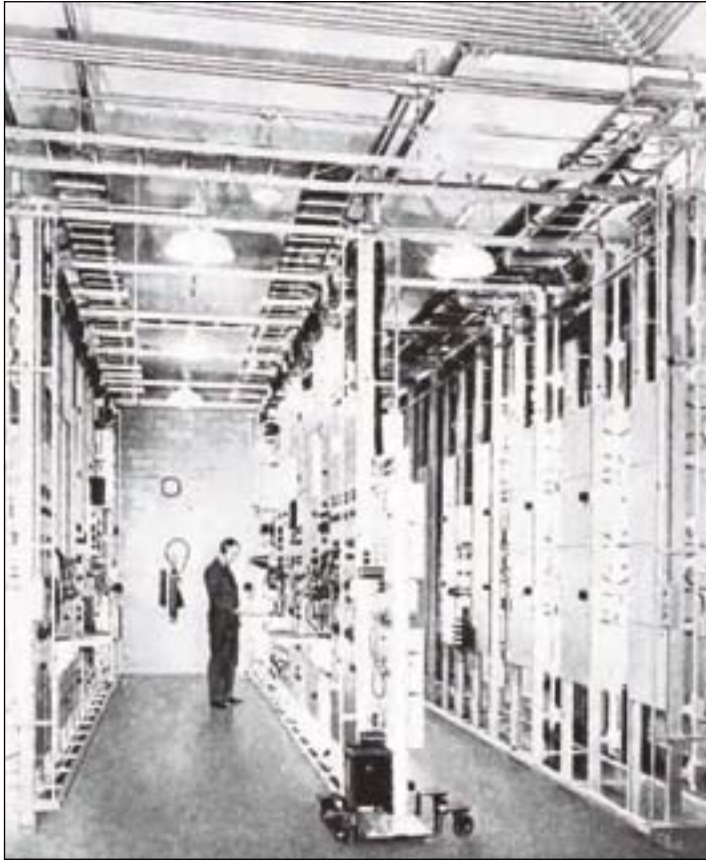


Figure 20: MUSA receivers at Manahawkin (Polkinghorn 1940, 310 © 1940 IEEE).

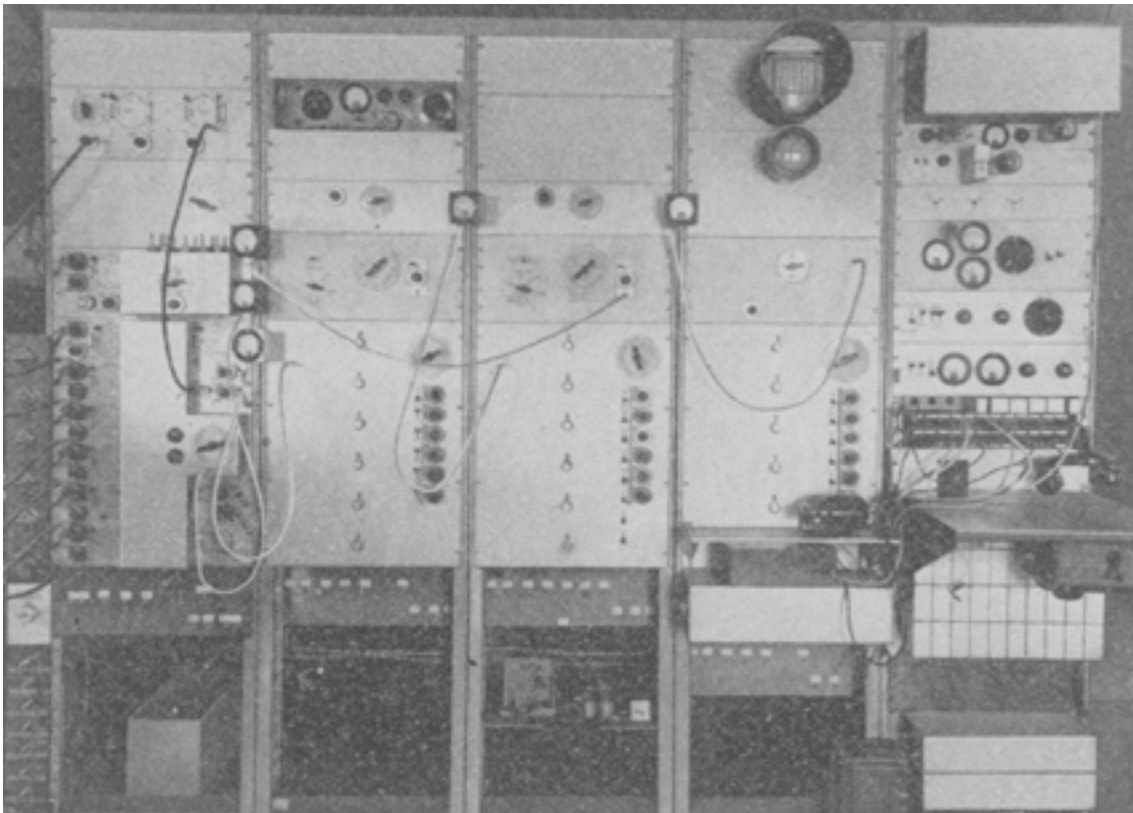
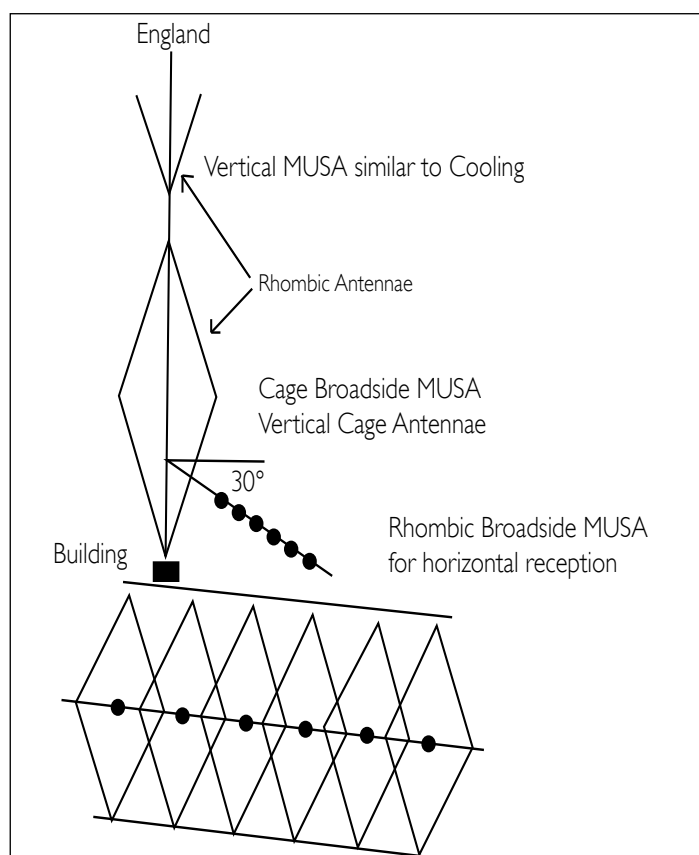


Figure 21: MUSA receiving equipment at Holmdel (Friis and Feldman 1937, 862 © 1937 IEEE).

Figure 22: Plan of the steerable antennae at Holmdel, New Jersey (Feldman 1939, 636 © 1939 IEEE).



arrays included a possible second vertical MUSA (BT Archives: TCB 2/102: 26/10/1937) and a horizontal MUSA. The presence of both horizontal and vertical antennae systems would enable a technique known as polarisation diversity reception to be employed (BT Archives: TCB 2/102: November 1936 WL/319).

In October 1939, Feldman published the results of two experimental antennae arrays constructed at Holdmel, New Jersey, to steer a receiving lobe horizontally (Figure 22) (Feldman 1939, 635). It is possible that masts mapped at Cooling from historic aerial photographs of 1946 were a unique unrecorded variation of a broadside MUSA array for horizontal steering (Figure 23).

Experience from Cooling and Manahawkin showed 'that the complexity and cost of the M.U.S.A. is worth while when applied to a group of important circuits carrying heavy traffic such as those between this country and the United States, but is probably not justified for more lightly loaded circuits' (Booth 1949, 87-8).

Unlike the mechanical operating system employed at Manahawkin, Cooling Radio Station was unique as it was controlled by an electrical phase-shifting system. The MUSA array was the last major technological development in the short-wave era and represented the ultimate short-wave receiving system (Bray 2002, 77, 79-80). Cooling Radio Station probably housed the most complex radio ever built (Hawkins 2004, 4).

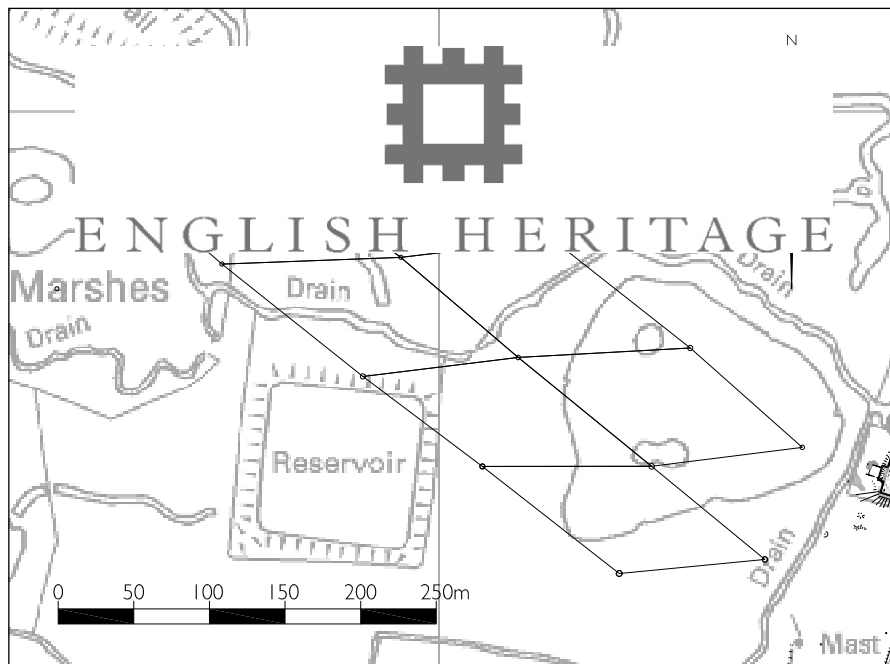


Figure 23: Plan showing the possible broadside MUSA at Cooling (© Crown Copyright and database right 2011. All rights reserved. Ordnance Survey Licence number 100019088).

## Rex of Ware

The laying of approximately 16 miles of transmission line led to the development of a new method for detecting small leaks in underground pipes. As site conditions meant that it was not possible to keep long sections of trench open, the normal method of testing for leaks could not be employed. Usually, leaks were detected by fixing pressure gauges along the line and measuring the difference in readings. Due to the specially flanged joints, the possibility of leaks was remote; however, when they did occur, they were often the size of a pinhole. The size of the holes meant that no noticeable difference in pressure was recorded (Hall *et al* 1940, 138).

Another technique employed to locate leaks at Cooling was one used by water companies. Listening rods were pushed into the ground at regular intervals in an attempt to hear the escape of any trapped air pockets. Employees of the Post Office failed to find any leaks using this technique (Hall *et al* 1940, 138).

The Post Office, therefore, set about developing a new method. Gas, with a distinctive and powerful odour, was pumped into the transmission line. Escaping gas would then be detected by employees walking the line and smelling the air. It was essential that the gas used was harmless to the materials used in the construction of the line, insoluble in water, and non-poisonous to animal life (Hall *et al* 1940, 139). Initially, the intention was to use 'one of the tear gases which are now available in ample amounts. It was felt, however, that the use of such a gas would invite staff trouble' (Hall *et al* 1940, 139). Eventually, amyl mercaptan, a sulphur compound derived from amyl alcohol, was chosen. To pump this gas into the tubing, a carburetting device was constructed so that a compressor could pump air through glass wool soaked in mercaptan (Hall *et al* 1940, 139-140).

During the first test, conducted on 10 February, gas was pumped into the tubing at Cooling for 90 minutes. Post Office employees then walked the line of the trench keeping slightly leeward whilst sniffing the air gently. Only one leak was located by carefully smelling the ground (Hall *et al* 1940, 140). 'It may be added that continual sniffing in a cold breeze seems to freeze the nostrils and make them either really or apparently insensitive' (Hall *et al* 1940, 140).

Compared to a human nose, a dog, with a far greater sense of smell, was deemed to have a better chance of detecting leaks if it could be trained to search for a specific 'non-game' scent. At the time, there was no precedent for what the Post Office attempted. After some initial trials, training concentrated on 'Rex of Ware', an experienced Labrador with a keen sense of smell (Hall *et al* 1940, 140).

Rex was familiarised with the smell through several days of 'intimacy' with it. Once he could detect the slightest hint, meat was buried next to a scented spot and Rex was induced to dig. As soon as Rex became proficient at this, a demonstration at Dollis Hill, the Post Office's Research Station, was organised. Five holes were drilled in a 50 yard (45.72m) lead pipe, through which amyl mercaptan was pumped. Immediately, Rex found the largest of the five holes; however, persuasion was required before he located the next three (Hall *et al* 1940, 140-1).

After the successful test at Dollis Hill, Rex was taken to Cooling for a trial. Amyl mercaptan was pumped through the underground transmission line for three hours prior to the start of the test. Three leaks were immediately located in the apparatus room which rapidly became uninhabitable with the smell. 30 yards (27.43m) from where the pipes entered the ground, Rex indicated a leak which was confirmed by a digging party. Rex identified a further 11 spots along the trench: seven were confirmed as leaks and one was a leak which had been repaired several days prior. Over-eagerness amongst the working party possibly led to the identification of three false locations (Hall *et al* 1940, 141).

Hall notes, 'Cooling Marshes are used for sheep and cattle grazing, and they must be absolutely alive with animal scents which would normally interest a dog. 'Rex of Ware' came through his four-mile trip each time without taking any notice of sheep, cattle, dogs or horses. At the end of a tiring day he showed that he was still a normal dog by joining enthusiastically in a rat hunt' (Hall *et al* 1940, 141).

### **Admiralty Direction Finding (D/F) Station**

On 31 March 1938, the Engineer-in-Chief's Office (Radio Branch) forwarded Mr. KHC Badger details of the 'small, "experimental Radio Station" to be erected at Cooling Marshes' (BT Archives: TCB 2/102: 8041). This site, among with several others across the country (BT Archives: TCB 2/102: 8041), was required by the Admiralty (BT Archives: TCB 2/102: Memo 05/05/1938). The proposed use of the site as an 'Experimental Radio Station' was the 'official description of this Station, as its real purpose is not to be disclosed at present' (BT Archives: TCB 2/102: 8041).

The 'experimental radio station' was a cover by the Admiralty to construct a Direction Finding (D/F) station. D/F was a technique which could locate the position of a radio transmitter (Macksey 2003, 26) by plotting the bearing of the same signal from a number of different receiving stations (Syrett 2002, 165).

At the outbreak of the Second World War, the Naval 'Y' Service, which was responsible for the Navy's D/F Stations, comprised of no more than 200 people who manned 50 receivers in 20 stations. The stations varied in size from Scarborough which had 20 receivers down to those which only had one. Cooling became operational in August 1939 just prior to the outbreak of war (The National Archives (TNA): Public Records Office (PRO): HW 8/98).

Prior to Bletchley Park breaking the German codes, D/F was one of the only methods by which the British could gain knowledge of enemy movements. Even once the codes had been broken, D/F proved a quicker method of intelligence gathering. This technique allowed the British to re-route transport from areas known to be patrolled by U-boats and dispatch attack ships and aircraft. D/F was, therefore, a vital tool in the war against the U-boats (Syrett 2002, 165, 171).

The negotiations for acquiring the land for these 'experimental Radio Stations' were conducted by the Post Office's Engineering Department (BT Archives: TCB 2/102: 8041). However, in the case of Cooling it was felt advisable that the Office of Works 'should approach Mr. Mugeridge as the latter might be confused if he is asked to negotiate practically simultaneously with two different bodies over sites only a few hundred yards apart' (BT Archives: TCB 2/102: 8041).

During the first few months of 1938, Badger contacted Cobb, the agent who had represented the landowners during the negotiations for Cooling Radio Station, setting out the requirements for the 'experimental Radio Station'. Cobb replied with Mugeridge's terms: a lump sum of £50 should be paid for the laying of underground cable; £25 should be paid for the use of the two stations until the end of 1938; and £5 which would cover the right to re-erect at any time. The terms also included compensation resulting from damage occurring during construction and use (BT Archives: TCB 2/102: 12/04/1938). Although Badger felt that the terms were rather 'stiff' (BT Archives: TCB 2/102: 12/04/1938), the Engineer-in-Chief's Office thought they might be the best obtainable. The matter was passed onto the Personnel Department to make a decision (BT Archives: TCB 2/102: 366 14/04/1938). Mugeridge's terms were not accepted.

Negotiations with Mugeridge over acquiring land for the transatlantic radio station and the D/F station resulted in confusion. During a meeting on the 30 May 1938 to resolve terms relating to the MUSA, Mugeridge contended that he was not being fairly treated. He felt that he should be paid the same rate per pole as land owners to the west (BT Archives: TCB 2/102: 10/06/1938). After further discussions:

'Mr Mugeridge was persuaded not to reopen the question of rate of payment which he was told it was understood that Mr Cobb had settled definitely with him, but Mr Mugeridge was very sore over what he considered to be the hard bargain that another Department of the

Post Office was trying to drive with him over an underground cable and some poles and a site for a small hut to the north of the main station building' (BT Archives: TCB 2/102: 10/06/1938).

It was only on returning to London, that the representatives at the meeting found out that the negotiations Mugeridge referred to were those associated with the D/F station (BT Archives: TCB 2/102: 10/06/1938).

After this confusion, it was decided on the 13 June 1938 that the negotiations for the two sites should remain separate. Once this decision had been reached, confirmation was required from the Admiralty of the amount they were willing to pay for land at Cooling. Commander Sandwich (possibly referring to Commander Sandwith) assured the Post Office that the Admiralty had no objection to paying up to £200 (BT Archives: TCB 2/102: 16/06/1938).

Commander Sandwith was one of three officers, the others being Lieutenant Commander Loehnis and Telegraphist Lieutenant Commander Bloodworth, who led the development of the Naval 'Y' Service prior to the Second World War (TNA: PRO: HW 8/98). The need to rapidly increase the number of D/F stations to improve the network's ability to obtain more reliable transmitter fixes was appreciated by Commander Sandwith (Beesly 2000, 16). Cooling was part of Commander Sandwith's expansion of the D/F network.

The intention was that the 35ft x 35ft (10.67m x 10.67m) and 6ft 6in x 6ft 6in (1.98m x 1.98m) plots required for the D/F station would be located on Post Office owned land. However, when the decision to keep the negotiations separate was taken, it was decided that the Admiralty actually required 75yd x 75yd (68.58m x 65.58m). This would provide sufficient space for two huts and room for future expansion. As an incentive for Mugeridge to sell, only 35ft x 35ft (10.67m x 10.67m) was to be fenced leaving the greater portion of the site available for grazing (BT Archives: TCB 2/102: 16/06/1938).

By August 1938, the vendor's agent had suggested that the purchase price for the plot of land should be £150 with a further payment of £50 for the installation of the underground cables. For the right to graze, Mugeridge was willing to pay 10/-per year (BT Archives: TCB 2/102: 40391 August 1938). On the 8 August 1938, Cobb confirmed that Mugeridge was willing to accept £175 as long as he could graze the unfenced land free of charge. Mugeridge also wanted all lawyers' and surveyors' fees paid in addition to the usual clause of compensation included in the agreement (BT Archives: TCB 2/102: 08/08/1938). On the 22 August 1938, the Director General of the General Post Office was informed that the offer had been accepted ten days earlier (BT Archives: TCB 2/102: 22/08/1938 and BT Archives: TCB 2/102: 12/08/1938). Notice of Mugeridge's right to graze the unfenced land was, however, not sent until the 27 October 1938 (BT Archives: TCB 2/102: 27/10/1938).

Badger informed Cobb that 'the Post Office are quite prepared to protect Mugeridge if he loses an opportunity of developing his land on their account, but I am told that in this case (unlike the other) it would be quite possible to divert the line to allow for land development and such diversion can be arranged for an alternative to compensation

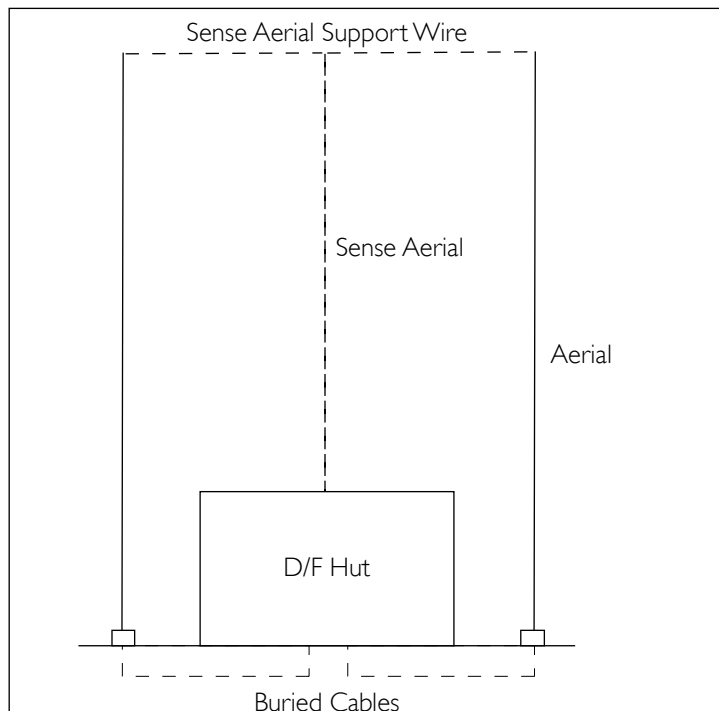


Figure 24: Cross section of a D/F hut. The hut was approximately 10ft x 10ft (3.05m x 3.05m) (after Nicholls 2000, 79).

where practicable' (BT Archives: TCB 2/I02: A/I 12/08/1938). On the 22 November 1938, the sum of £196 7s 4d was requested from the Accountant General's Department to cover the costs associated with purchasing the land (BT Archives: TCB 2/I02: 22/11/1938). The purchase was completed four days later (BT Archives: TCB 2/I02: 28/11/1938).

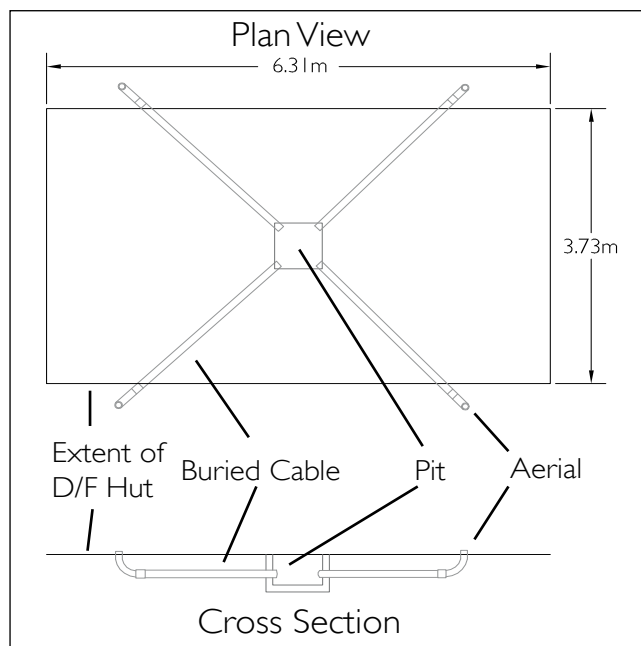
Part of the settlement included the right to build and maintain a footbridge over the dyke to the D/F station (BT Archives: TCB 2/I02: 06/09/1938). The bridge (26x2ft [7.92x0.61m]) would cross the dyke at right angles and be constructed from two runners (9x3in [0.23x0.08m]) supporting short planks. Along one side, a hand rail was to be erected. It was intended that the bridge would support cables either laid into wooden troughs or attached to runners by metal clips. At either end, trellis gates would prevent cattle from crossing (BT Archives: TCB 2/I02: A/I 13/08/1938).

The D/F Station at Cooling Marshes consisted of a small wooden hut and four masts (Figure 24 and Figure 25; BT Archives: TCB 2/I02: 17/12/1942). Telephone and power cables were laid between the D/F Station and the main receiving station. These were buried to a depth of approximately 2ft (0.61m) with the lead covered power cables placed in a wooden trough (BT Archives: TCB 2/I02: January 1943 DLA/Prov.4.). To access the station, 300 yards (274.32m) of trackway was also laid (BT Archives: TCB 2/I02: 09/01/1943).

Whilst in service, Cooling D/F Station was operated by the Admiralty Civilian Shore Wireless Service and was subject to nightly air raids (BBC [www.bbc.co.uk/ww2peopleswar/stories/25/a8259825.shtml](http://www.bbc.co.uk/ww2peopleswar/stories/25/a8259825.shtml) accessed 26/07/2010). It was surplus to requirements by the 17 November 1942 (BT Archives: TCB 2/I02: 17/11/1942).



Figure 25: Proposed layout of the D/F station at Cooling (after BT Archives: TCB 2/102).



The site of the redundant D/F Station was deemed to be too close to existing antennae to be of any use to the Post Office (BT Archives: TCB 2/102: 28/01/1943). Enquires by the Regional Director (BT Archives: TCB 2/102: 26/11/1942), confirmed that the Engineering Department could see no likelihood of the site being required for future use (BT Archives: TCB 2/102: 05/12/1942).

Once it was decided that the site was surplus to Post Office requirements, the advice of the Ministry of Works was sought as to whether it was optimal to wait until after the end of hostilities to sell (BT Archives: TCB 2/102: 17/12/1942). The Ministry recommended that the Post Office induce Mugeridge to make an offer on the site, as no other party was likely to be interested (BT Archives: TCB 2/102: 22/01/1943). It was also written into the Post Office's contract with Mugeridge his right of pre-emption over the land (BT Archives: TCB 2/102: 17/12/1942).

By the 28 January 1943, Mugeridge had purchased, at a reasonable price, and removed the hut and fencing (BT Archives: TCB 2/102: 28/01/1943). However, the Post Office was convinced that Mugeridge was unlikely to pay anything approaching the sum they originally purchased the land for (BT Archives: TCB 2/102: P.O. 30/40391 February 1943).

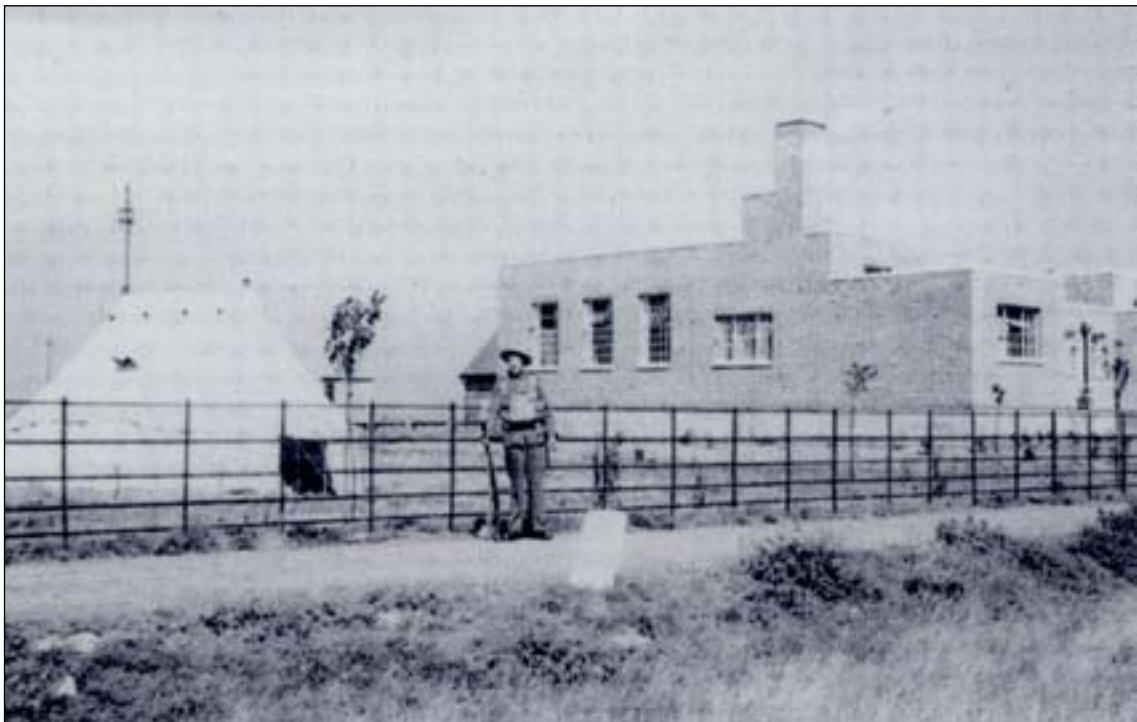
Due to the shortage of poles during the Second World War (BT Archives: TCB 2/102: 07/06/1943), the Post Office removed the redundant D/F antennae from the site (BT Archives: TCB 2/102: 08/06/1943). These had been cleared by the 19 July 1943 (BT Archives: TCB 2/102: 19/07/1943). However, the Post Office had no intention of removing the underground cables (BT Archives: TCB 2/102: 08/06/1943). The labour costs and other charges associated with this were felt to exceed the value of the recoverable material (BT Archives: TCB 2/102: 08/06/1943 W3/LJB/WOI24).

By the beginning of May 1943, Mugeridge had made an offer for the site at the rate of £35 per acre; however, the Post Office was endeavouring to obtain a better deal (BT

Archives: TCB 2/102: 05/05/1943). Mugeridge had increased his offer to £50 for the whole site by the end of May, plus he agreed to cover his own costs (BT Archives: TCB 2/102: 27/05/1943). This new offer was only five pounds less than price of the site as valued by the Inland Revenue (BT Archives: TCB 2/102: 01/09/1943). The Post Office, after:

'Taking into consideration the contrasting circumstances in which the site was acquired and is now being offered to the vendor and the fact that failing an agreement with Mr. Mugeridge the matter will need to be taken to arbitration, an event which the Post Office will no doubt wish to avoid, it is thought that in all circumstances no better offer will be forthcoming and this Department is therefore prepared to recommend that this offer be accepted' (BT Archives: TCB 2/102: 27/05/1943).

In October 1943, a letter was drafted to Messrs Arnold Tuff and Grimwade, solicitors acting on behalf of Mugeridge, accepting his offer of £50 for the site of D/F station (BT Archives: TCB 2/102: October 1943 HNG/MGS). Mugeridge's cheque was received by the Post Office on the 23rd February 1944 (BT Archives: TCB 2/102: 23/02/1944).



*Figure 26: Armed guard outside Cooling Radio Station presumed to be during the Second World War (courtesy of Frank Turner).*

## **The Second World War**

For security reasons, it was decided that all point-to-point radio-telephone circuits should be closed down at the outbreak of the Second World War. Consequently, in early 1939, arrangements were being made to adapt all telephone receiving and transmitting equipment for telegraph operation (Mumford 1947, 23-4). With the cancelling

of radiotelephone circuits, no direct speech channels were available to America. Communication was only possible via undersea telegraph cables and wireless telegraph as the technology to lay a transatlantic telephone cable was not available (Hay 1946, 55).

However, the radiotelephone circuit between the USA and the United Kingdom was quickly reopened (Mumford 1947, 23-4). Although the date when operation of this circuit via another receiving station recommenced is unknown, it was certainly in use by 5 July 1940 when a warning was circulated about the dangers of indiscretion over the transatlantic radio telephone (TNA: PRO: CAB 116/32 05/0701/1940). Cooling Radio Station eventually became operational on 1 July 1942. The circuit to America remained available to a limited number of correspondents throughout the war (Mumford 1947, 25).

Although the precise nature and role of the work at Cooling (Figure 26) during the Second World War is uncertain, one can hypothesise that the MUSA channels were used for the more important conversations. This was due to the reliability and clarity of the signal received.

### Post-Second World War

In 1955, the Post Office was concerned that the proposals to establish a National Nature Reserve on the High Halstow Marshes would prevent them from erecting antennae in the future (TNA: PRO: FT 17/1: 16/07/1955). Although the Nature Conservancy planned to exclude the radio station from their proposed Nature Reserve (TNA: PRO: FT 17/1: 13/07/1955), they could not agree to any future development of the radio station until they had seen plans (TNA: PRO: FT 17/1: 21/07/1955).



Figure 27: Boundary of the proposed Nature Reserve (orange) and the area the Post Office wanted to be kept clear for aërials (green) (TNA: PRO FT 17/1).

Plans were afoot by July 1955 to expand the number of antennae at Cooling. Although the precise location of these new masts was not settled upon, the Post Office desired that a vast area of the marshes should be kept free (Figure 27) for the erection of antennae of 150ft (45.72m) or more in height. These were intended to be purely static receiving antennae which required little in the way of maintenance (TNA: PRO: FT 17/1: 19/11/1955). Mr Hayden, of the Nature Conservancy, had no objections (TNA: PRO: FT 17/1: 19/12/1955). Although the nature and layout of the Post Office's plans are unknown, historic aerial photographs from 1961 clearly show three new rhombic and one square array (Figure 43) (NMR RAF/58/4646 F96 F43 346 28-AUG-1961 and NMR RAF/58/4137 F96 F43 64 9-FEB-1961).

In July 1959, the Post Office was developing plans to erect a wireless telecommunications mast on Halstow Marshes. The proposed mast was of wooden construction and would stand at a height of approximately 250ft (76.20m) (Figure 28; TNA: PRO: FT 17/2: 22/07/1959). Construction of the mast would enable the Post Office to observe sun-spot emissions which would be of value in improving overseas wireless communications services. The next peak of sun-spot activity was not expected for another decade; however, the Post Office was anxious that the mast was brought into service by spring 1960 (TNA: PRO: FT 17/2: 25/08/1959). The mast would also enable Post Office engineers to carry out experiments on wireless antenna design (TNA: PRO: FT 17/2: 07/12/1959). By the time the Post Office met with the Nature Conservancy to discuss their plans, they had already cleared wayleaves and conducted test boring (TNA: PRO: FT 17/2: 25/08/1959).

Construction of the tower was opposed by the Nature Conservancy as it had the potential to cause considerable disturbance to wildlife research at the planned National Nature Reserve (TNA: PRO: FT 17/2: 24/07/1959). However, failure to erect the mast at the Post Office's preferred location could set their experiments back by approximately one year. The Nature Conservancy felt that one year's worth of research was incomparable to the perpetual disadvantage to wildlife research. At the time negotiations over the establishment of a Nature Reserve were at a delicate stage. '[T]he certainty of improvement of wireless telecommunications was [therefore] being balanced against the uncertainty of the Reserve being extended on to the marsh' (TNA: PRO: FT 17/2: 25/08/1959).

On the 16 September 1959, the Planning Department of Kent County Council informed the Ministry of Works that they were going to recommend that permission to erect the mast should be rejected. Their objection was based on the serious effect the mast could have on a site of Special Scientific Interest. Furthermore, 'in view of the prominent position of the site the design of the mast is inappropriate and should ... be of slender metal construction ... if it is to be erected' (TNA: PRO: FT 17/2: 16/09/1959).

Due to the Nature Conservancy's objections to the proposed location of the telecommunications mast, the Post Office identified another potential site at the far western end of the MUSA array (TNA: PRO: FT 17/2: 07/04/1960). Provisionally, the Nature Conservancy agreed to the erection of the tower at the new site (TNA: PRO: FT 17/2: 08/06/1960); however, there is no evidence from the historic aerial photographs that

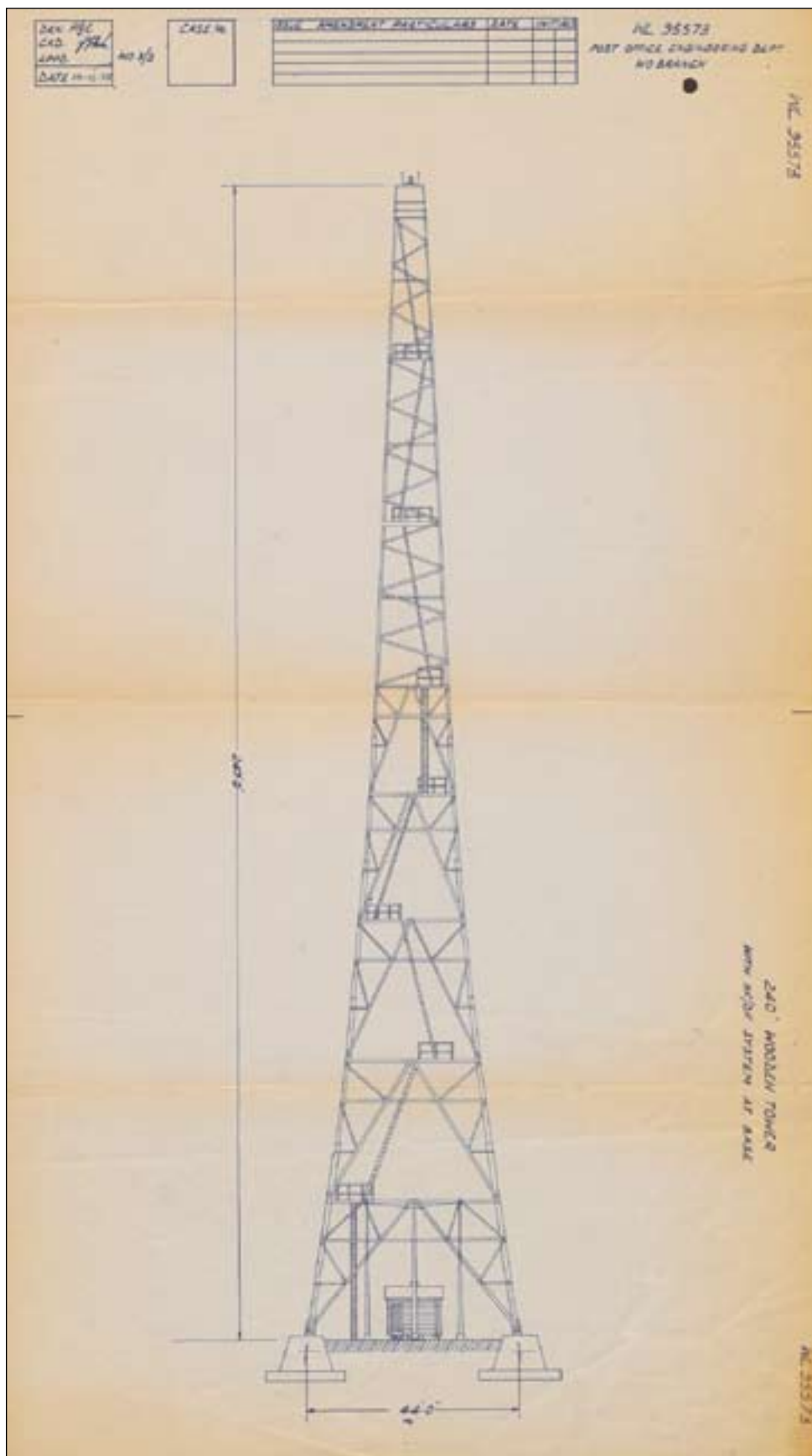


Figure 28: The tower the PO intended to erect in Cooling Marshes (TNA: PRO: FT17/2).

construction ever occurred.

By December 1959, the Post Office was planning the construction of an experimental antenna array known as the 'Multiple Direction Universally Steerable Aerial System' (MEDUSA) at Cooling (TNA: PRO: FT 17/2: 07/04/1960). Approval was sought from the Nature Conservancy; however, consent could not be given until they had further details as 'it might be worth remembering that both mythologically and zoologically Medusa is lethal to those who come into contact with her!' (TNA: PRO: FT 17/2: 14/04/1960).

The Post Office's plans involved erecting 288 masts grouped into six circles of 48. Each mast consisted of four telegraph poles standing at a height of 30ft (9.14m). Surrounding each mast would be a buried earth mat ploughed in by a tractor. Once erected, maintenance would be negligible and the MEDUSA had an expected life expectancy of 15 to 20 years (TNA: PRO: FT 17/2: 21/04/1960). As the majority of the array to be constructed outside the Nature Reserve, the Nature Conservancy had no objection presuming their 'operational area' was avoided (TNA: PRO: FT 17/2: 09/05/1960).

### **The 'Multiple Direction Universally Steerable Aerial System' (MEDUSA)**

In 1959, DW Morris and G Mitchell of the Post Office Research Station published a paper on the principles of 'A Multiple-Direction Universally-Steerable Aerial System for H.F. [High Frequency] Operation'. 'The system comprises a number of omnidirectional unit antennae whose outputs (in the case of reception) may be brought approximately into phase with each other for any desired combination of frequency and direction by means of direction-control equipment which is basically a high-speed computer' (Morris and Mitchell 1959, 555).

Development of a highly-directive antenna array, capable of being steered in elevation and azimuth, offered improved performance on short-wave radio channels. The MUSA, which provided an overall superior circuit performance to a single rhombic antenna, was only steerable in elevation and was restricted to the New York-London channel (Morris and Mitchell 1959, 555). Whilst a 'universally-steerable aerial system could be used on any short-wave circuits and would be capable of coping, not only with variations of elevation angle caused by changes in ionospheric conditions along the path of the signal, but also with any lateral deviations arising from ionospheric tilts or absorption in the auroral zones. The system would provide a means of maintaining consistently high aerial gain when receiving signals from mobile stations on ships or aircraft' (Morris and Mitchell 1959, 555). MEDUSAs also offered the possibility of reducing the interference from unwanted transmissions (Morris and Mitchell 1959, 555).

In principle, signals picked up by the MEDUSA antennae were fed via equal length cables and wideband amplifiers to radio frequency distribution units (Figure 29). This enabled sufficient output to supply the individual receivers, ensuring each receiver received a signal from each antenna. After the signal had passed through the distribution units, the output from each antenna was switched via a four-way switch to one of four cables. The direction control equipment, when informed of the frequency and direction of the signal required by each receiver, computed the relative phase of each antenna



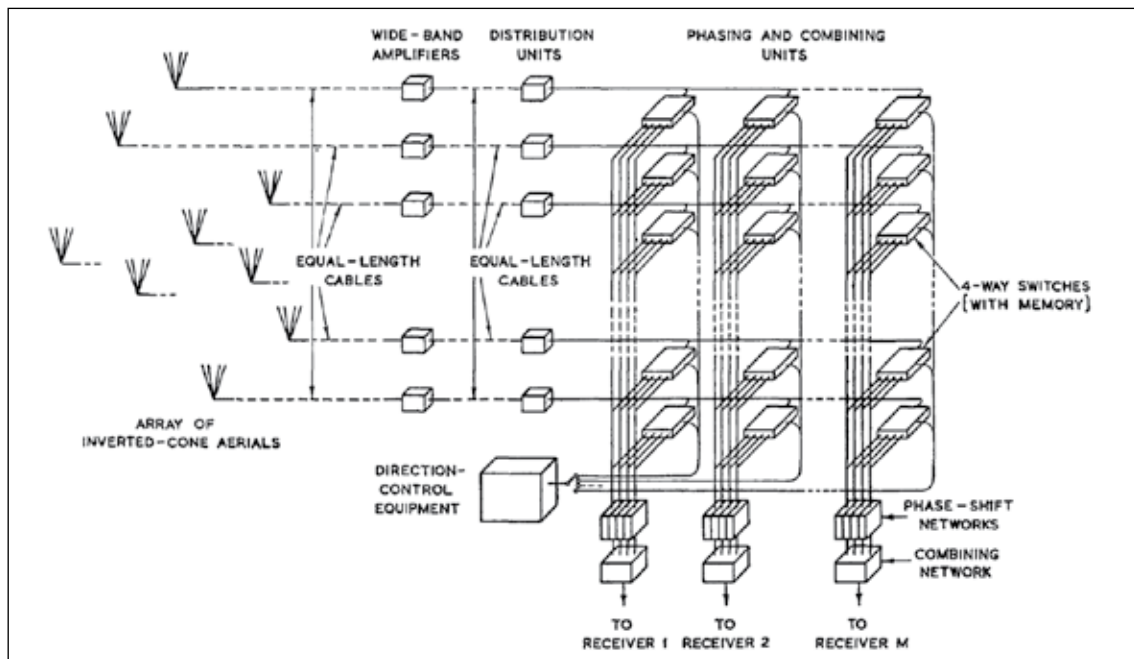


Figure 29: Schematic diagram of a MEDUSA (Morris and Mitchell, 1959: 556 © 1940 IEEE).

output. This equipment then switched the four-way switch to ensure that the antenna output transmitted down the appropriate cable. The outputs of the antennae were thus grouped on the four cables according to the receiver's required signal vector. After passing through the cable, the signal passed through wideband phase-shift networks and combining circuits. This brought the outputs into phase and combined them to form the input signal for each receiver (Morris et al 1963, 1570-1).

Each receiver was associated with a phase shift network of four-way switches, whilst the direction-control equipment was common to all receivers. The direction control equipment was only required for setting-up which could be achieved on a time sharing basis. Consequently, each switch incorporated a memory so that phasing instructions could be retained when the direction-control equipment was changing the switches for another receiver (Morris et al 1963, 1571).

One of the advantages of the MEDUSA was that it could be adjusted according to the prevailing transmission conditions. Signals arriving at the antennae were displayed on a monitor providing the means of determining whether an adjustment was necessary. To cover all possible directions of the required signal, phasing instructions were supplied from the direction-control equipment to the four-way switches of the monitor branch. This enabled the antennae system to be steered in small steps over a range of azimuths and elevations. Displayed on the monitor was a measure of the received signal level, and the variation with direction of steer was visible on a cathode ray tube display. From this the preferred direction of steer could be ascertained (Morris et al 1963, 1571).

During the construction of a MEDUSA array, it was possible to economise on equipment by arranging the unit antennae in a number of identical groups. This enabled the phasing and combining of the antenna outputs to occur in two stages. Equal-length cables

connected the antennae to phasing and combining equipment at the centre of each group. Primary phasing instructions are common to all the groups and allow one to economise on switch memories and registry units. Group outputs are then transmitted over equal-length cables to further equipment located at the centre of the array. Here all the group outputs are phased and combined to provide a steered system output (Morris et al 1963, 1573).

Savings could also be made by arranging unit antennae in pairs symmetrically about the centre of each group. Phasing instructions were, therefore, only computed and memorised for one antenna within each pair as the phase shift of the pair were identical, only differing in sign (Morris et al 1963, 1573).

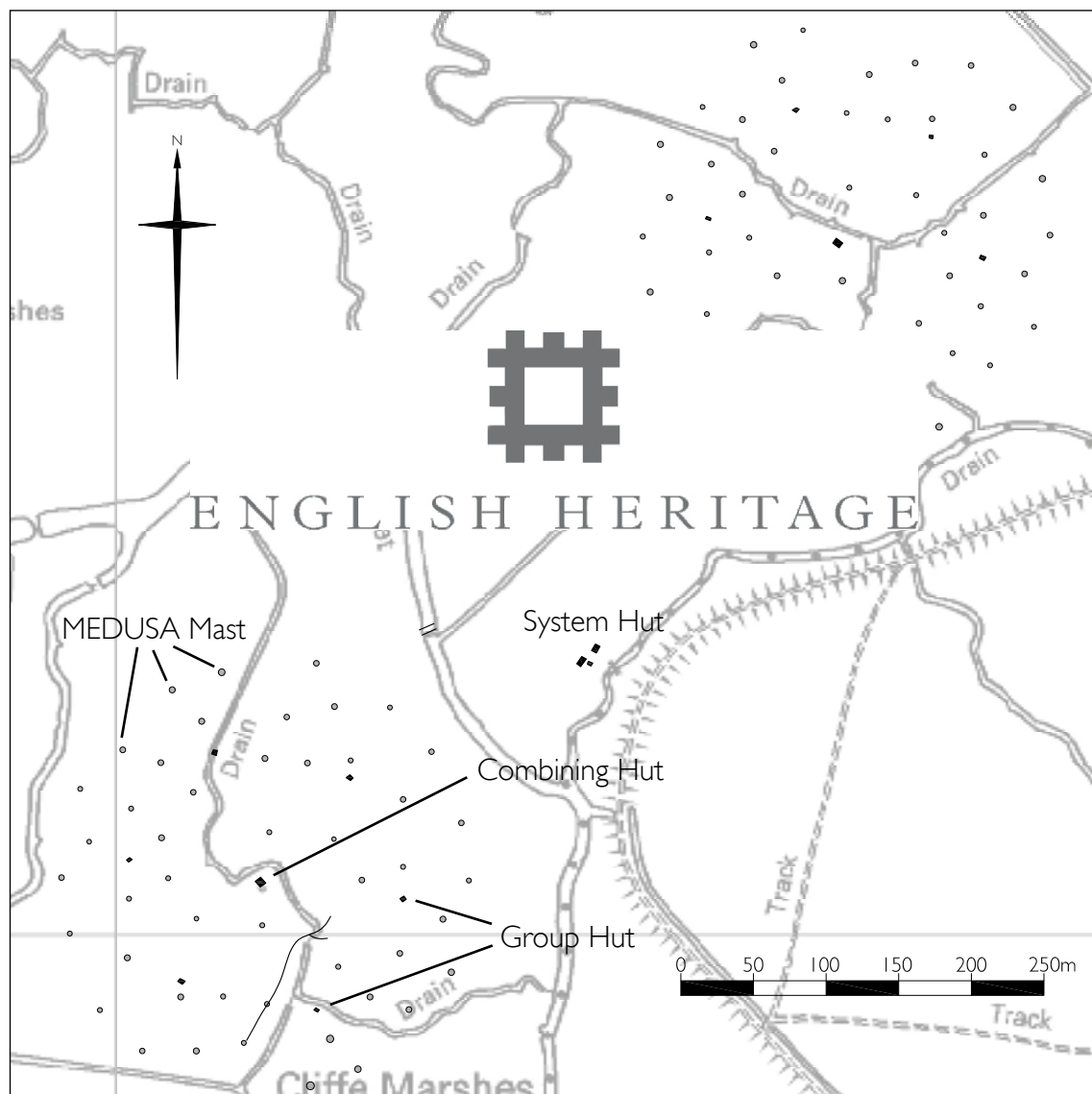


Figure 30: The MEDUSA at Cooling mapped from aerial photographs. Surveyed at 1:2500. Not reproduced to scale (© Crown Copyright and database right 2011. All rights reserved. Ordnance Survey Licence number 100019088).



The saving achieved through grouping unit antennae and arranging them in symmetrical pairs can be illustrated in a 400 antenna array. If the MEDUSA was laid out as a fully irregular array, the number of phasing instructions, switch memory circuits, and registry units required per receiver is 400. However, if the array is arranged in 10 groups of 20 symmetrical pairs with the groups in five symmetrical pairs, the total number of phasing instructions, switch memory circuits, and registry units required is 25 (Morris et al 1963, 1573).

## **The Experimental MEDUSA at Cooling**

Cooling was chosen as the site for the experimental MEDUSA as the antenna array required uniform ground constants. This ensured that phase changes from ground reflection were similar for all antennae. High ground conductivity was also desirable as it permitted adequate low-angle reception by the vertical polarised antennae (Morris et al 1963, 1573). The MEDUSA was constructed at Cooling for partly the same reasons why it was also chosen for the MUSA.

The experimental MEDUSA at Cooling was described by Morris et al (1963, 1574) as comprising two groups of antennae separated by 600m. Each antenna group had a diameter of 300m. The size of the groups was a compromise between fitting the array into existing land boundaries, whilst ensuring they were large enough to enhance measurements of specular components. Furthermore, the size of the groups restricted cable length and costs. The two groups could be combined to form a larger array or used as two individual antenna systems. Each group contained 48 antennae which was the minimum required to simulate a group array (Morris et al 1963, 1574).

Within each antenna group, layout was influenced by several factors. Tests conducted on one-third scale models indicated that a minimum spacing of 30m between full-scale antennae was required. This ensured that antenna interaction effects were kept to a minimum. Furthermore, across the array, antenna density had to be reasonably uniform yet forming an irregular pattern. In each group, 24 pairs of antennae were arranged in a common design (Morris et al 1963, 1574-5). Historic aerial photographs clearly show the identical layout of the two groups (Figure 30).

The unit antennae which formed the MEDUSA were an inverted-cone monopole, seven metres high, with a flare angle of 30° (Figure 31). Suspended from a self-supporting wooden structure were 16 wires. Buried beneath the antenna was an earth mat 16ft (4.88m) by 30ft (9.14m) from which radial wire emerged and connected to a base plate. The base plate was supported 18in (0.46m) above ground level to avoid flood damage (Morris et al 1963, 1574).

At the centre of each group was a hut containing antenna amplifiers, radio frequency distribution equipment, and two phasing and combining units which included the four-way switches (Figure 32). Outputs from these huts were transmitted via coaxial cables to a system hut near the centre of the whole array. It was here that the outputs from the two groups were phased and combined into a system output. The system hut contained the switch memory which controlled the four-way switches in the group huts. Finally, the

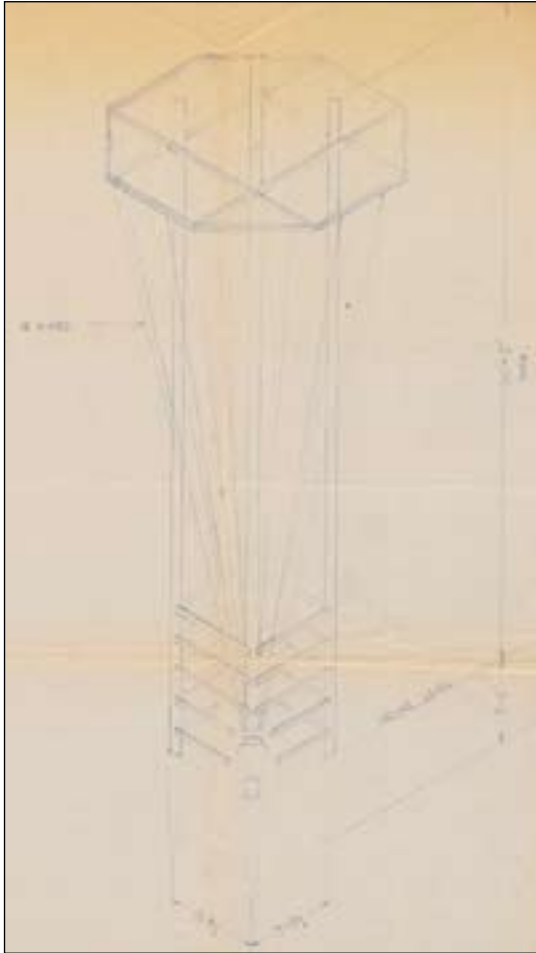
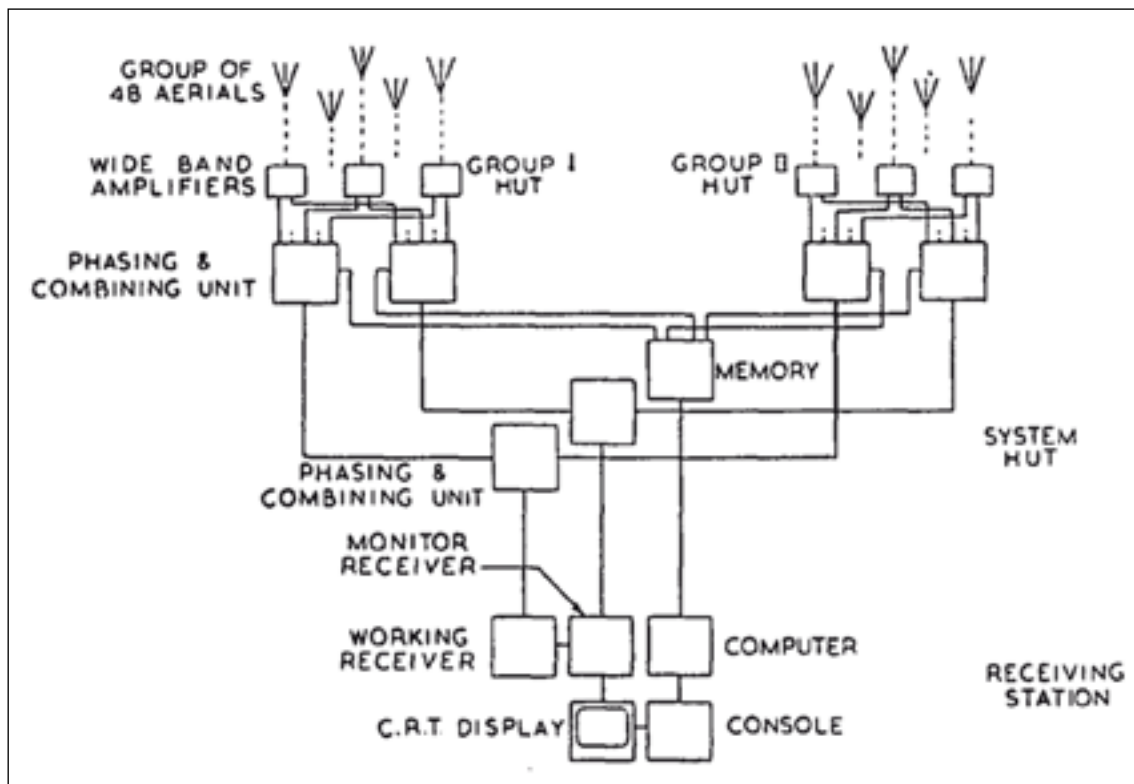


Figure 31: (left) The aerals which made up the MEDUSA (TNA: PRO FT17/2).

Figure 32: (below) Schematic diagram of experimental MEDUSA system developed at Cooling Radio Station (Morris et al 1963, 1574 © 1963 IEEE).



system output was transmitted over coaxial cables to the receiving station (Morris *et al* 1963, 1574).

The layout of the MEDUSA as mapped from historic aerial photographs, indicates that phasing and combining of the antenna outputs occurred in three stages (Figure 43). Equally spaced within the two groups were six structures (NMR RAF/58/4646 F96 F43 347 28-AUG-1961). Here the outputs from eight antennae were phased and combined. The output was then transmitted over equal length cable to equipment at the centre of each group for further phasing and combining. Signals were then transmitted via equal length cable to the centre of the array where the outputs were finally phased and combined.

The coaxial cable used in the construction of the MEDUSA was of equal electrical length regardless of the distance. All cabling, including excess, was buried at a uniform depth of six inches (0.15m) below the ground. This insured that the effects of temperature variations on phase tracking were kept to a minimum (Morris *et al* 1963, 1575).

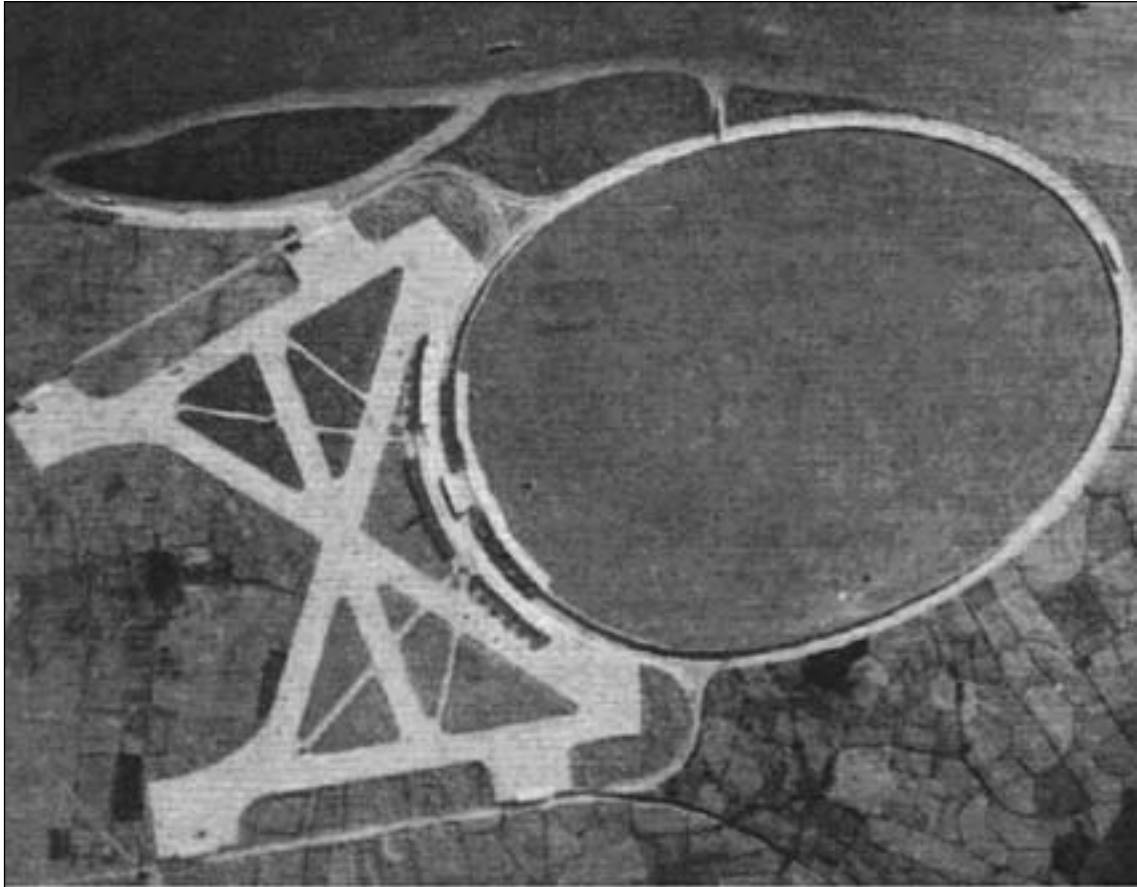
Control facilities of the experimental MEDUSA were 'comprehensive and flexible. The direction-control equipment enables the system to be steered to receive any signal in the frequency range 5-25Mc/s from any bearing and any angle of elevation and to scan in rapid sequence over a range of bearings or elevations or both combined. Control parameters, such as the scanning ranges in the two dimensions and the speed of scan, are adjustable, with several choices in each case' (Morris *et al* 1963, 1574).

## Cooling Airport

Throughout the 20th century, various proposals have been developed for the construction of an international airport on Cooling Marshes. In 1943, Guy Morgan and Partners prepared a scheme for Mr FG Miles of Phillips and Powis Aircraft. This proposal was based on Miles' idea for a combined land and marine airport (TNA: PRO: RAIL 1188/170: 17/05/1945). However, construction of an 'air base in this area would have a serious effect on the Post Office Radiotelephone Receiving Station at Cooling Marshes' (BT Archives: POST 33/5313: 19/02/1947).

To conform to the expected post-war aircraft requirements, the proposed runways were going to be 2½ miles long by 600ft wide (182.88m) (Figure 33). The airport would also include an artificial lagoon with shelters enabling flying boats to be serviced as fast as contemporary land planes. Construction of a lagoon would also overcome the problems of exposed tidal conditions, rough water and floating obstructions (TNA: PRO: RAIL 1188/170 PLA Monthly: The Air Age and the Port of London Master Plan for Sea-Air Port).

The proposed airport would offer a take-off rate of one aircraft every 10 minutes, 24 hours a day. Furthermore, built-in capacity would enable this to increase eventually to a take-off every two minutes. It was predicted that the airport would see eight million passengers per year (TNA: PRO: RAIL 1188/170 PLA Monthly: The Air Age and the Port



*Figure 33: One of the plans for an international airport and flying boat base at Cooling (Flight 1943, 115).*

of London Master Plan for Sea-Air Port).

In the proposals, access to the road and rail terminals was via subways which were connected to the loading level of the seaplane floating platforms by lifts. Beneath the road and rail network would be an underground passenger concourse which contained customs, baggage weighing and all other necessary amenities (TNA: PRO: RAIL 1188/170 PLA Monthly: The Air Age and the Port of London Master Plan for Sea-Air Port). Morgan's scheme was estimated to cost in the region of £20 million (TNA: PRO: RAIL 1188/170: 29/07/1945).

Guy Morgan and Partners developed a further proposal for an airport at Cooling in 1945. This plan was essentially 'one trans-ocean airport and two Continental airports within the same area. Each of these component airports has runways in three different directions' (TNA: PRO: RAIL 1188/170: Scheme for Proposed Air Terminal on the East Side of London: 4). The airport would comprise nine runways and a minimum of three flight ways in an artificial lagoon. Capacity would be provided for 75 transoceanic and 150 Continental airplanes per hour. The artificial lagoon was designed so that seaplanes could be serviced under shelter (TNA: PRO: RAIL 1188/170: Scheme for Proposed Air Terminal on the East Side of London: Part II: 1-2).

On the 19 February 1946, the Post Office contacted the Secretary of the Ministry of Aviation in relation to 'reports which have recently appeared in the Press, stating that your Department has commenced a detailed examination of a scheme for the establishment of a civil air base at Cliffe' (BT Archives: POST 33/5313: 19/02/1947). The Ministry of Civil Aviation had failed to consult the Post Office over the possible construction of an airport at Cooling. On the 27 April 1947, the Prime Minister, Clement Richard Attlee, rebuked the Ministry of Aviation for this failure: 'Your department seems seriously at fault in making assumptions about the telephone line without proper inquiries at the time when Cliffe was first considered as an alternative' (BT Archives: POST 33/5313: 28/04/1947). The Ministry of Civil Aviation's plans for construction a civil flying boat base at Cliffe were dropped by the 31 January 1949 (BT Archives: POST 33/5313: 31/01/1949).

In 1953, Morgan was still intent on obtaining approval for the proposed flying boat base at Cliffe: 'It would be a great help to us to know, off the record, whether it would be possible, and how seriously inconvenient, for your G.P.O. Broadcasting Station to be removed from the Cliffe site. In confidence, one of the reasons given for the turning down of the scheme when it was nearly through, was this station' (BT Archives: POST 33/5313: 27/01/1953). The Post Office estimated that the construction of a new station in 1953 would cost in the region of £¼ million: furthermore, a station 40 miles further from London would add an additional £20,000 annual land line charge (BT Archives: POST 33/5313: 03/02/1953). Cooling Radio Station was partly responsible for the failure of the plans to construct an international airport at Cliffe.

## CSA Ltd

Cooling Radio Station was eventually closed in 1965 (Turner 2000, 3). This was partly the result of the advent of transatlantic telephone cables in 1956 as well as the launching of the Telstar satellite in 1962. These technological advancements heralded a new era in global communications (Hawkins 2004, 5).

Around 1970, CSA Ltd was looking for a suitable outdoor site for testing antennae. Eventually they settled on Cooling Radio Station's vacant apparatus building and leased it from the farmer who owned the land. By the 1980s, the building had started to sink into the marsh and was being targeted by vandals. The decision was taken to demolish the structure above the ground floor, whilst retaining the generator room. On to this room was constructed a second storey with a computer-controlled antenna rotator fixed to the roof (Collins pers comm).

Surrounding the building, various experimental high frequency antennae and rotating masts were erected. These were used for testing antennae used for radio and TV broadcasting. From the late 1990s, CSA's work became focused on base station antennae for cellular networks which were tested at Cooling. In 2005, CSA's factory and laboratories at Strood were closed and the remaining test facilities based at Cooling were removed (Collins pers comm). The site is currently owned by the RSPB.

## DESCRIPTION AND INTERPRETATION OF THE REMAINS

The following section provides a detailed description of the surviving remains of the apparatus building, topographical features associated with the radio station, and features mapped from historic aerial photographs.

### Apparatus Building Survey

#### Summary



*Figure 34: The remains of Cooling Radio Station (© English Heritage).*

Today, Cooling Radio Station (Figure 34) comprises a reinforced concrete basement on which a platform is defined by a double skinned capped wall. This structure stands at a height of approximately 3m. On the north-east corner the generator room survives with a second storey constructed in the 1980s. To the west and south-east, two bays extend from the main platform (Figure 35). All measurements are approximate.

#### Basement

Extending beneath the whole of the apparatus building, sits a poured reinforced concrete 'basement' standing at a height of 1.44m on the eastern elevation (1.70m on the western elevation). All faces of the concrete basement which can be seen from the southern approach road have been painted green. This is a later addition as in places the paint covers repairs to the original brickwork. Approximately 0.15m above ground level there

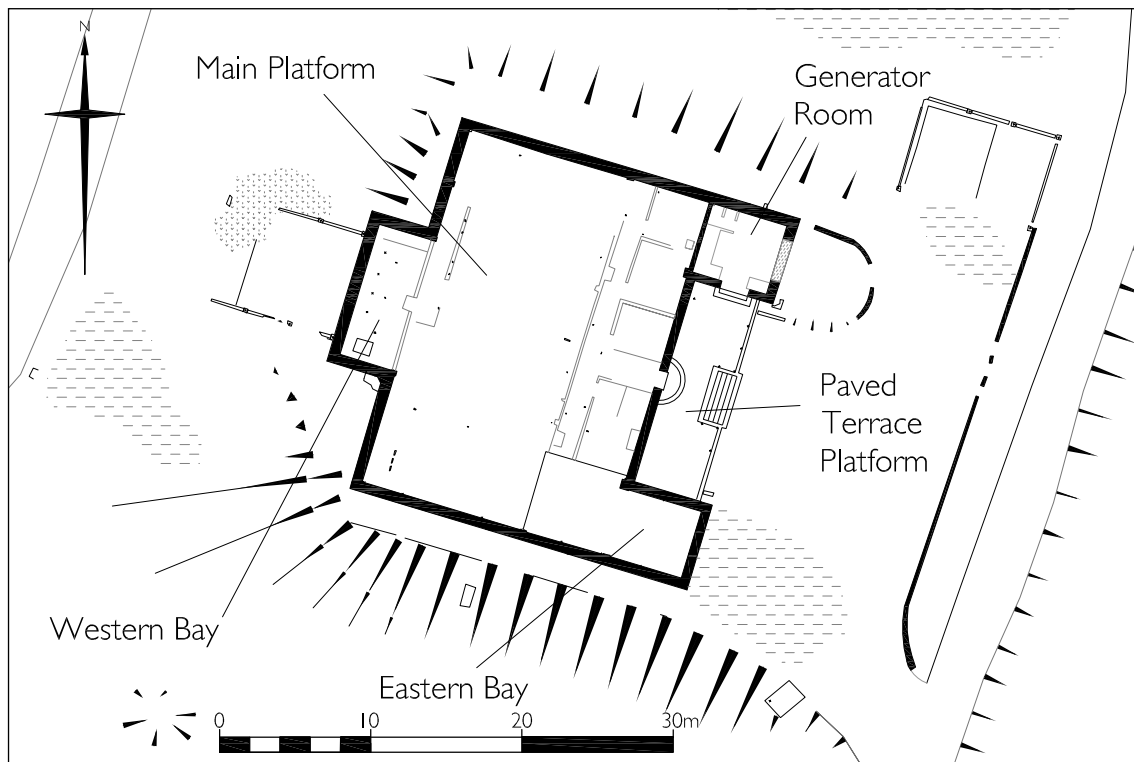


Figure 35: Remains of the apparatus building. Structure surveyed at 1:100, earthworks at 1:1000. Not reproduced to scale (© English Heritage).

is a chamfer running the entire length of the basement.

Set within the concrete of the eastern elevation is an Ordnance Survey (OS) benchmark. There are also 16 rectangular air vents (0.46m x 0.24m) set into all the faces of the external wall of the basement. The eastern vent of the northern elevation has been smashed to enable a pipe to be inserted.

Protruding from the centre of the base of the southern face, opposite a BT manhole cover, are two circular metal pipes 0.09m in diameter. One contains a circular iron pipe, while the other encloses two types of electrical cabling. Set into the external northern elevation of the concrete basement is an iron pipe encased in ceramic, metal fixing bolts, two oval discs and an iron loop.

Running south from the southern elevation of the western bay is a witness mark for a walkway and flight of stairs which ran along the western side of the reinforced concrete basement. Beneath this is a sub-rectangular vent and two ceramic pipes (0.18m diameter). Arranged one above the other (0.54m and 1.18m above ground level), both contain a smaller circular iron pipe. The top pipe also contains a small plastic tube. On the northern elevation of the western bay, there are the remains of fittings associated with a drain pipe. There is also a single 0.12m long iron pipe protruding from the reinforced concrete.

Although access to the basement was not possible during the site visit as a result of deteriorating asbestos lagging, the following is a description based on the structural

report produced by The Morton Partnership Ltd (2010), on behalf of the RSPB, and the authors' observations through broken air vents.

Presently, the only access to the basement is via a small opening (0.8m wide, 0.58m, high and 0.42m deep) in the reinforced concrete on the northern elevation of the western bay. The wooden door for this hatch still survives. On the floor of the western bay, a fixed metal sheet covers another possible sub-terrace access hatch.

Beneath the western bay are two small rooms partitioned by a brick wall supporting a concrete beam (Figure 36). The doorway between these rooms still contains a wooden door painted green; attached to this are two hooked fittings which may have acted as a form of locking mechanism. To the west of the door are the remains of a number of horizontal wooden supporting slats. Within these rooms, fixtures for holding pipes to the ceiling still survive. Two asbestos lagged pipes run along the northern face of the northern room and enter the main chamber to the east via holes in the reinforced concrete.



Figure 36: Photograph showing the two rooms beneath the western bay (© English Heritage).

To access the main chamber from these rooms, one has to crawl through a horizontal slot (0.6m high) in the reinforced concrete adjoining wall. In the northern room, this slot has been blocked up with approximately 10 courses of brickwork: only three courses



were constructed in the southern room.

The roof of the main chamber is supported by two pairs of reinforced concrete columns (0.91m x 0.91m). These columns support a reinforced concrete beam (0.46m deep by 0.23m wide) which runs the entire width of the building. In places, smaller beams run at right angles to the main beams. Surviving in the main chamber are various pipes and associated fittings (Figure 37). Witness marks of the wooden shuttering used when pouring the concrete can be seen on the roof.

The walls of the main chamber are constructed from reinforced concrete capped with approximately four courses of brickwork. Interspersed within this brickwork are a number of concrete pillars supporting the roof. These pillars are not visible externally, indicating that they do not extend the full width of the wall.



*Figure 37: The main chamber of the basement (© English Heritage).*

Although the brickwork provides some support in the basement, it was not intended as load bearing. This construction technique allowed the greatest flexibility for future use of the site. Brick walls are easier to manipulate than reinforced concrete if further infrastructure was required in the basement. Using this construction technique on external walls also permitted outwards expansion of the apparatus building with limited cost and disruption.

There are two horizontal access slots within the reinforced concrete eastern wall of the main chamber. These lead to two further rooms, one in the north-eastern corner, and the other in the south-eastern. Enclosed by a brick wall to the north, the southern room

contains a large pile of concrete and brick rubble. Within the concrete roof, there is an access hatch covered by a metal sheet. This access is not visible from the main platform as it is covered by the later concrete slab. To the east, a further room can be accessed through another horizontal slot in the concrete. The reinforced concrete in the east and west walls are capped with ten courses of brickwork.

### **Paved Terrace Platform**

Access to the paved terrace platform, situated in front of the entrance to the main platform, is via five concrete steps capped with dark grey bricks (Figure 38). These bricks (0.23m x 0.07m x 0.11m) also cap the edging to the paved terrace platform; later repairs used a narrower brick. The concrete slabs (0.61m x 0.76m) forming the paved terrace slope slightly to the east permitting better drainage of this flat surface. Running along the eastern edge of this platform are a number of circular plastic fittings possibly associated with a hand rail. Set into one of the concrete paving slabs in the north-western corner of the terrace, is a metal ring, the function of which is unknown.



*Figure 38: Photograph showing the main entrance to Cooling Radio Station and the paved terrace platform (courtesy of Frank Turner).*

The western and southern edges of the platform are defined by a 1.46m high wall capped with concrete coping stones. Constructed from two skins of bricks, the 'external' wall is English Bond red bricks (0.22m x 0.06m). Set within the mortar, three courses above the terrace, are two bands of slate which acted as damp protection. Repairs,

associated with the 1980s demolition, have been made to the brickwork surrounding the access steps from the paved platform terrace to the main platform. The southern wall has also been repaired where a doorway once stood. Below these repairs is a concrete footing (1.68m x 0.21m). The northern edge of the platform is defined by the generator room.

Two semi-circular concrete steps lead from the terrace to the main platform to the west (Figure 39). On these are traces of red paint with a white band painted around the top. Set into the top step are two bricks and a metal bar is set within the concrete base of the doorway. At the northern side of the terrace platform, two pre-cast concrete steps lead to the entrance to the generator room.



*Figure 39: Photograph showing the paved terrace platform and the generator room (© English Heritage).*

## **Main Platform**

The main platform is defined by a low wall formed of a double skin of brickwork. In places, plastic pipes have been punched through this to aid drainage. The brickwork defining the southern elevation appears to be original. Most of the southern wall of the western bay has been rebuilt using the same bricks as the repairs to the entranceway to the main platform. Set into this wall are the remains of four poured concrete steps which connected the external walkway (see above) to a bricked up doorway (Figure 10).

The inner wall, which is not keyed into the external wall, is brick-built with a sloping brick coping. Construction of the internal wall around the entrance to the main platform

was from bricks with vertical channels moulded into their stretchers. Either side of the entrance, a matching pair of iron 'T' bars was set flush with the wall, above which are iron bolts.

At the north-western corner of the eastern bay, a concrete capped buttress is partly covered with concrete render and plaster. This plaster is similar to that on the concrete beam in the western elevation of the generator room (see below). The presence of plaster indicates that these surfaces were once inside a building. Bull-nosed bricks were used to form the southern corners of this buttress. To the south is an opposing buttress constructed from bull-nosed bricks. The majority of the brickwork which defines the eastern bay is original; however, on the southern side the doorway to the paved terrace platform has been bricked up and repaired.

Next to the southern face of the poured concrete floor of the main platform, a concrete slab (0.07m thick) was placed, the function of which is unknown. To the west of the buttress on the southern elevation, two bricks, one above the other, jutted out from the internal wall. Nearby is a concrete rendered buttress with a metal core: on the eastern face, ceramic tiles survive. Rendering witness marks survive on the internal face of the southern elevation of the main platform.

Inserted into the inner face of the southern elevation are three pairs of iron 'T' bars (0.06m wide). Less than one metre apart (0.87m), the 'T' bars appear to be associated with two iron poles set into the concrete floor 0.30m either side. In front of each group, there is evidence for an iron bolt set into the poured concrete floor.

Repairs have been made to the inner wall of the western elevation. Inserted into the northern face of the western bay are two iron 'T' bars. At the corners of the western bay with the main platform, are two small concrete buttresses capped with concrete. To the north of the western bay, there is a concrete rendered buttress with metal core. This buttress appears not to be keyed into the wall which runs behind it.

Substantial repairs had been made to the inner face of the northern elevation of the main platform. In front of these later repairs, there is the stub of a concrete rendered buttress. There is also a concrete rendered stump in front of the western elevation of the generator room. On the poured concrete floor of the main platform, witness marks to the east indicate the location of internal divisions and to the west where cabling and equipment were once secured.

## **Generator Room**

Besides the concrete basement, the only part of the apparatus building surviving is the generator room (Figure 40). Originally a one storey building (at a height of 4m), during the 1980s a second floor was added increasing the height by 2m. The original brickwork was laid down as English Bond whilst the later additions are only stretchers. Running along the eastern and southern elevations, near the top of the original brickwork, is a chamfered edge. The earlier brickwork stands at the original height for the generator room. Capping the roof of the generator room are cast concrete slab panels supported

by two concrete beams.

Within the eastern elevation, an original window has been bricked up with reused bricks from the demolished apparatus building. The mortar used, however, is consistent with the later repair work. Above the blocked up window, is a flat headed brick arch. Two PVC windows protected by metal roller shutters were built into the second floor addition on the north and south elevations.

The door to the generator room is protected by the addition of a metal roller shutter similar in design to those used over the windows. Above the door is a flat topped relieving arch. To the east, a small rectangle in the original brickwork has been blocked with a lighter coloured brick. Beneath is a small plastic circular fitting similar to those on the paved terrace and associated with the hand rail (see above). Repairs, linked to the demolition of the apparatus building, have been made to the external south-western corner of the generator room. Next to this corner, a buttress is capped with concrete.

Constructed from a double skin of brickwork, the internal wall of the first floor is original. Witness marks on the concrete floor mark the location of the generator. In the western elevation, an access hatch which originally led from the main room onto the roof of the generator room has been blocked (Figure 38). This is no longer visible externally as the wall has been rebuilt.



*Figure 40: The eastern elevation of the remains of Cooling Radio Station. Later additions to the generator room are clearly visible (© English Heritage).*

The external wall of the western elevation has been completely rebuilt. Set into this wall, beneath the access hatch and visible both internally and externally, is a concrete beam coated with pink rendering. During demolition of the apparatus building, the concrete beam survived set into the internal wall. Whilst rebuilding the external wall, the bricklayers built around the beam incorporating it into the wall.

## Topographical Survey of Environs

### Summary

To the east of the apparatus building, a courtyard is defined by a low brick wall. Within this courtyard survives brickwork associated with two decorative planting beds. North-east and west of the apparatus building are the footprints of two metal framed structures (Figure 41).

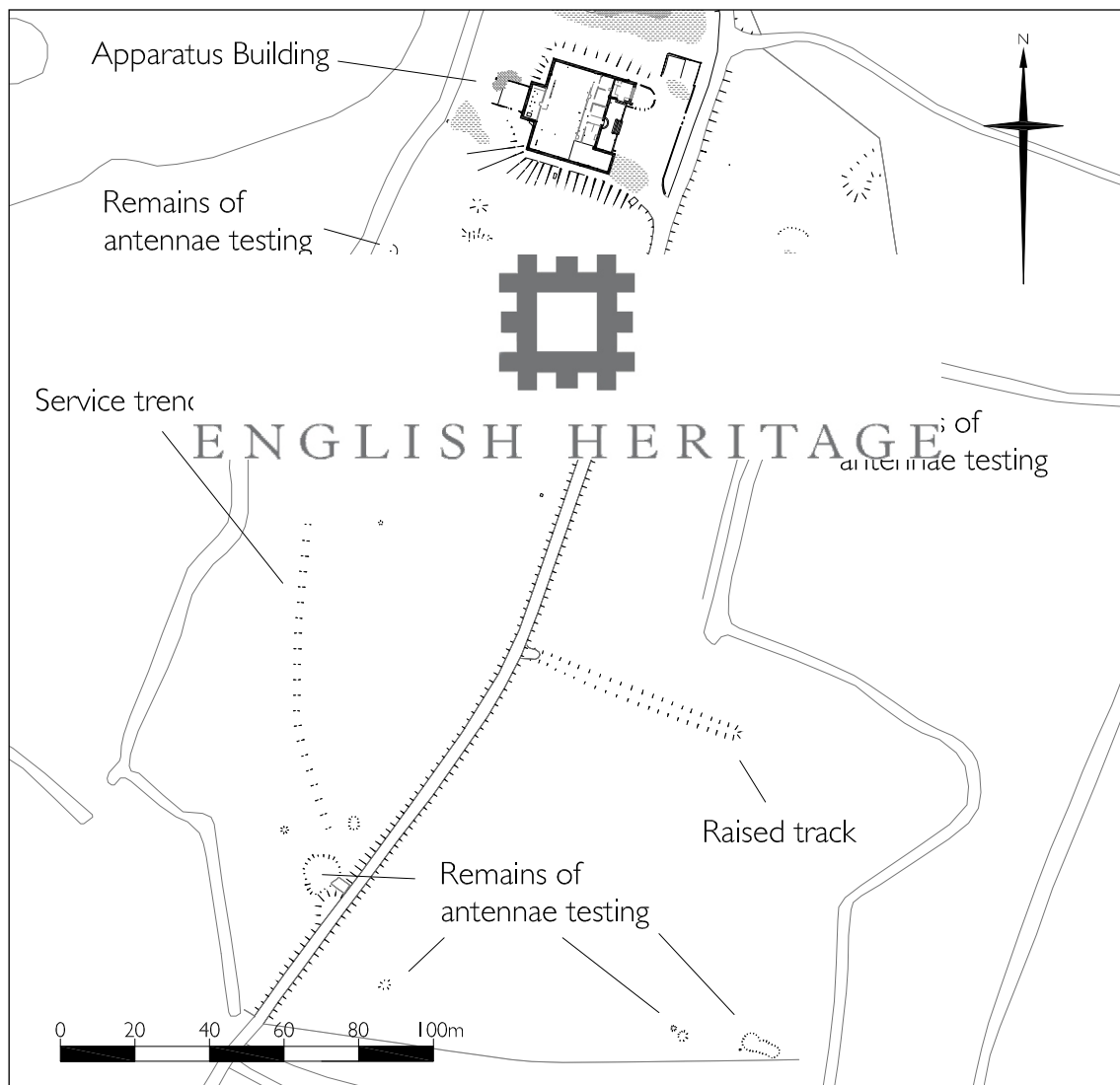


Figure 41: Topographical survey of Cooling Radio Station environs. Structure surveyed at 1:100, earthworks surveyed at 1:1000. Not reproduced to scale (© Crown Copyright and database right 2011. All rights reserved. Ordnance Survey Licence number 100019088).



## Structures

To the east of the generator room there is a concrete slab which indicates the location of a demolished structure (6.5m x 9.4m). This is defined by a low brick wall regularly interspersed with concrete stumps. At the centre of each stump is an iron bolt which supported the metal frame of the brick structure. 15m to the east of the generator room is the remains of another structure (6m x 9m). This was constructed using a similar technique (Figure 42). However, it appears that there were two phases to this structure, with a smaller building constructed on a similar footprint.

## Courtyard

To the east of the apparatus building, a single course of decorative brickwork defines a tarmac courtyard. Within this, two semi-circular planting beds, abutting the apparatus building, are defined by similar brick walling. Running along the northern and southern elevation of the apparatus building are tarmac walkways edged with concrete curbing.



*Figure 42: The concrete slab in the foreground indicates the location of a demolished structure (© English Heritage).*

## Other Features

Within the immediate vicinity of the apparatus building, various depressions indicate the location where concrete slabs have been removed. These are associated with the later use of the site as an antenna testing centre. Two linear features, possible associated with drainage and a track way, were also recorded (Figure 41).

## Historic Aerial Photography Mapping

### Summary

The full extent of the MUSA and the MEDUSA experimental antenna arrays was mapped from historic aerial photographs (Figure 43). Various other, previously unknown, antenna arrays were also identified. After CSA Ltd moved into the apparatus building, various antennae were erected in the immediate vicinity. 300m to the north of the apparatus building the D/F Station was also identified from the historic aerial photographs.

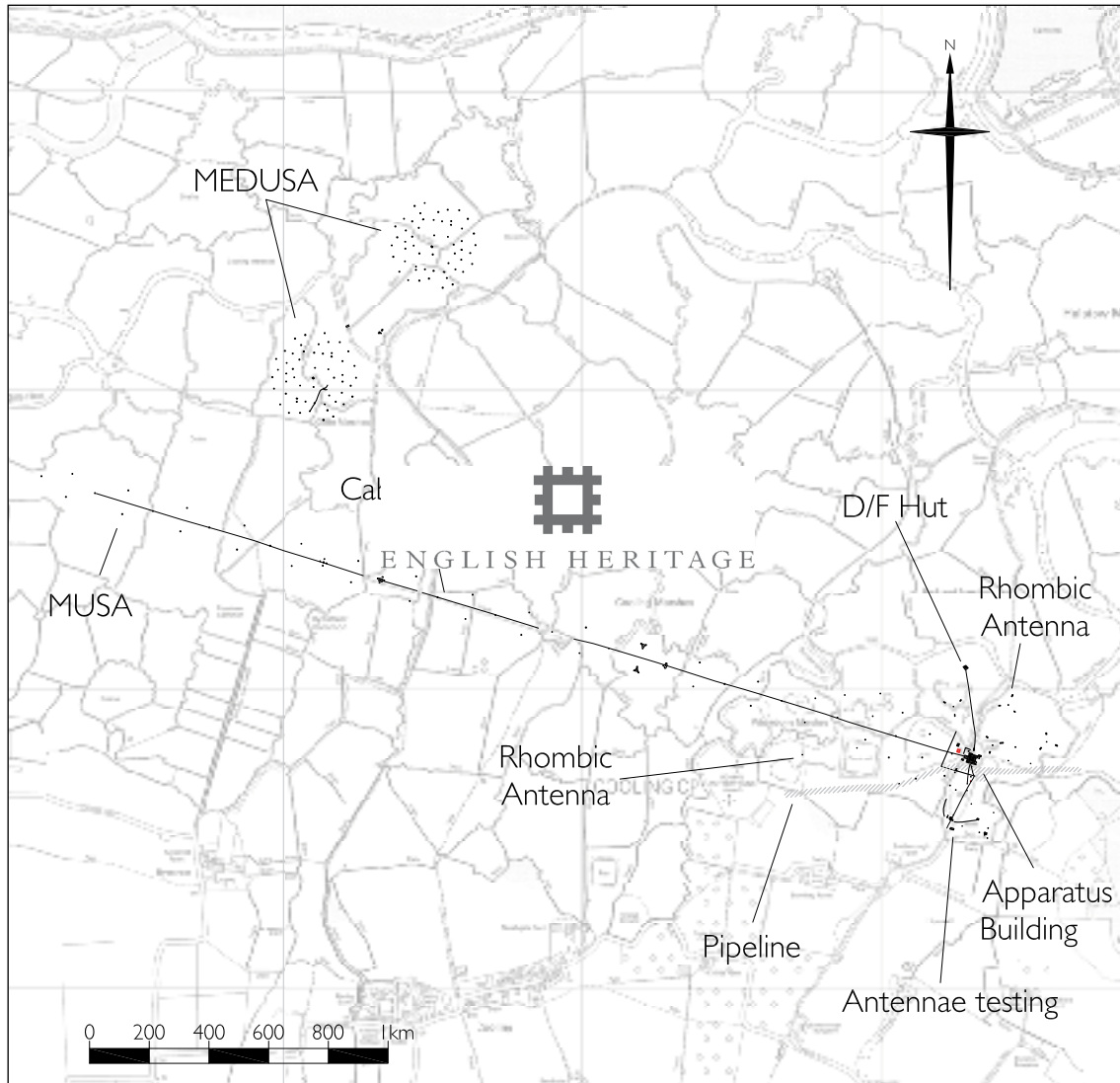


Figure 43: Aerial photographic transcription of Cooling Radio Station and environs. Surveyed at 1:2500. Not reproduced to scale (© Crown Copyright and database right 2011. All rights reserved. Ordnance Survey Licence number 100019088).



## MUSA

The MUSA array comprised of a number of antennae stretching for two miles on a south-east north-west bearing. By 1946 (NMR RAF/106G/UK/1444 4001 1-MAY-1946) RAF Photography) a further six masts had been added to the MUSA towards its eastern. It is possible that these formed an experimental variation of the broadside MUSA constructed at Holmdel, New Jersey (see above).

## D/F

300m to the north of the radio station, the remains of the D/F station were identified. This structure was connected to the radio station via underground cables (NMR RAF/540/496 F20 4191 12-MAY-1951). Evidence for the location of the D/F station is in the form of a 'X' shaped vegetation mark.

## MEDUSA

By 1961, the MEDUSA experimental antenna array had been constructed two and a half kilometres to the north-west of the apparatus building (NMR RAF/58/4646 F96 F43 347 28-AUG-1961). This consisted of two circular groups (300m diameter) of 48 masts in a random arrangement. Although random, the layout of each group was identical. Spaced evenly along a circular path, 100m diameter from the centre of each group, were six structures. These structures probably held phasing and combining equipment and were connected to four pairs of antennae. This would have economised on the equipment required (see above). Central to each group was a structure which contained further phasing and combining equipment. Located at the centre of the whole array were a further three structures. In these, the signal was subjected to final phasing and combining.

## Cooling Radio Station

In 1946 there were a number of buildings close to the northern edge of the apparatus building. To the west of the building, was located a rectangular (9m x 10m) mound which had been removed by 1951. Nearby, a concrete slab indicates the location of a demolished building (NMR RAF/106G/UK/1444 4001 1-MAY-1946). This slab was removed during the construction of the reservoir. The apparatus building's compound, which was reduced in size by 1961 (NMR RAF/58/4646 F96 F43 346 28-AUG-1961), was enclosed by a fence (NMR RAF/106G/UK/1444 4001 1-MAY-1946). Along the road leading to the apparatus building, ornamental trees had been planted.

Prior to 1961, the antenna arrays at Cooling underwent expansion. To the south of the apparatus building, four masts were erected prior to 1951 in a rectangular arrangement (47.5m x 57m) (NMR RAF/82/713 695 6-FEB-1953). By 1961, a further four masts had been erected in a square (81m x 81m) 200m to the south. At the centre of this array was a small structure connected to the roadway by a small track (NMR RAF/58/4646 F96 F43 347 28-AUG-1961). Two large (150m x 340m) rhombic arrays were also constructed prior to 1961 (NMR RAF/58/4137 F96 F43 64 9-FEB-1961). Aligned with the MUSA, these acted as point-to-point receivers for communications from the USA. The masts of the northern rhombic antenna were supported by three concrete slabs arranged around

their base. Attached to this array was a smaller rhombic antenna (140m x 51m) also aligned with the transmitter in Lawrenceville, New Jersey (NMR RAF/58/4137 F96 F43 64 9-FEB-1961).

### CSA Ltd

By the 1970s, all the masts associated with the radio station at Cooling had been removed. In their place were a number of antenna bases associated with CSA's testing facilities. Construction of a pipeline, during the 1970s, stripped an area of land (20m wide) along the southern elevation of the apparatus building (NMR OS/7350 087 17-AUG-1978).



Figure 44: Aerial photograph showing the apparatus building and part of the MUSA. The telegraph poles forming the antennae are highlighted (NMR RAF/82/713 0695 6-FEB-1953 English Heritage (NMR) RAF Photography).

## DISCUSSION AND CONCLUSION

The surveys and accompanying research has thrown new light on this unique and largely forgotten transatlantic short-wave receiving station. Built in the late 1930s, but not coming into service until 1942, Cooling Radio Station was the most advanced and technically complex radio ever built. The antenna array at Cooling represented the ultimate short-wave receiving system.

The MUSA array comprised 16 rhombic antennae stretching for two miles aligned with the transmitting station in Lawrenceville, New Jersey: only two other MUSAs are known to have been constructed in the world. Evidence from historic aerial photographs indicates that a second, experimental horizontal MUSA was also constructed. The layout of the horizontal MUSA was similar to an experimental one built at the Bell Laboratory test facilities in Holmdel, New Jersey. The presence of the radio station and the unique antenna array prohibited the construction of a major international airport and flying boat base in the late 1940s.

Cooling Radio Station was also the site of an experimental 'Multiple Direction Universally Steerable Aerial System' (MEDUSA). The MEDUSA had the potential to be the next major development in global short-wave communication. Cooling was eventually closed down in the 1960s when satellite and transatlantic telephone cables became the dominant technology.

During the early years of the Second World War, Cooling was also the site of an Admiralty direction finding (D/F) station. This station played a vital role in the war against the U-boats.

After the Post Office had left the site, Cooling Radio Station was occupied by CSA Ltd as a test facility for experimental antennae. Under their ownership, the majority of the apparatus building was demolished above the basement. The only room surviving was the one which housed the generator. Onto this was constructed a second storey with a computer controlled antenna rotator fixed to the roof.

## SURVEY METHODOLOGY

A temporary base station was surveyed using a Trimble R8 survey grade GNSS receiver working in Real Time Kinematic mode (RTK). The position of the point was adjusted in real time to the National Grid Transformation OSTN02 via the Trimble VRS Now Network RTK delivery service. This uses the Ordnance Survey's GNSS correction network (OSNet) and gives a stated accuracy of 0.01-0.015m per point. Further detail, including three survey stations, were surveyed using a Trimble R8 survey grade GNSS receiver working in RTK mode with points related to an R8 receiver configured to the temporary base station. The survey data was downloaded into Korec's Geosite software to process the field codes and the data transferred to AutoCad software for plotting out for graphical completion in the field.

The apparatus building, and other features which were obscured by trees, were surveyed using a Trimble 5600 series total-station theodolite combined with a Trimble TSC2 controller in relation to a temporary GPS base station. The stations were surveyed in sequence to form a closed traverse of 4 stations. The survey data was downloaded into Korec's Geosite software to process the field codes and the data transferred to AutoCad software for plotting out for graphical completion in the field scales of 1:1000 for the topographical survey and 1:100 for the building survey. Further building detail was recorded using standard graphical techniques of offset and radiation from a network of points previously located with GNSS. The survey plan and additional report illustrations were completed using AutoCad and Adobe Illustrator software and the report was prepared for publication using Adobe InDesign software.

The survey data has been archived at English Heritage's public archive, the National Monuments Record, Kemble Drive, Swindon.

All readily available aerial photographs were consulted and examined stereoscopically where possible. The best photographs for specific information were selected for rectification. Only features associated with Cooling Radio Station were recorded.

The aerial photography transformations were carried out using the University of Bradford's Aerial5.29 photographic rectification program. Control information was taken from the digital copies of current OS 1:2500 scale maps. All digital transformations are, therefore, accurate to within circa 5m of true ground position, and typically less than 2m to the base map.

The transcription was produced in AutoCad by tracing the archaeology from the transformed and georeferenced aerial images. There were some difficulties with the rectification/transformation as some of the control points are obscured by vegetation and boundaries have been removed and altered since some of the key photographs were taken.

## GLOSSARY

Amplitude: Amplitude is the measure of strength or how loud a SIGNAL is (Graham and Lowe 1991, 6).

Amplitude Modulation: Low FREQUENCY (LONG-WAVE) signals require large amounts of energy to transmit over long distances. To overcome this, methods were developed to imprint low frequency signals onto high frequency CARRIER WAVES. Amplitude modulation involves a carrier wave with a constant frequency, but whose AMPLITUDE is varied proportionally to the message signal (Figure 45; Graham and Lowe 1991, 99).

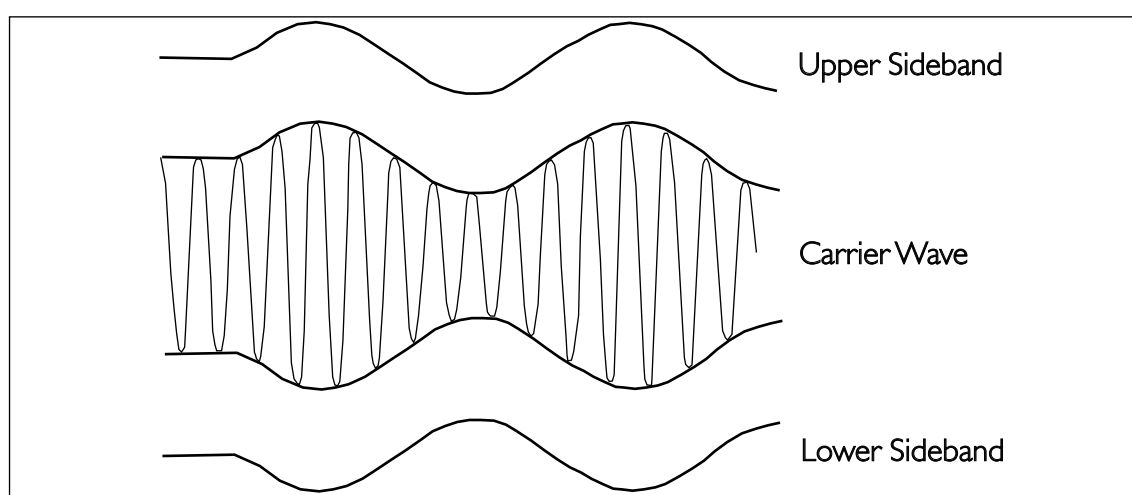


Figure 45: The process of amplitude modulation creates three signals: the upper sideband, the lower sideband, and the carrier wave (after Dunlop and Smith 1994, 42).

Antenna: 'A device constructed to transmit or receive RADIO WAVES' (Graham and Lowe 1991, 7).

Azimuth: The horizontal angle of a compass bearing (Allen 1990, 76).

Bandwidth: The bandwidth defines the range of FREQUENCIES which can be transmitted effectively over a communication channel (Graham and Lowe 1991, 12).

Carrier Wave: 'A SIGNAL generated for the purpose of carrying another message signal at a particular point in a FREQUENCY SPECTRUM' (Graham and Lowe 1991, 24).

Cathode Ray Tube: Cathode Ray Tubes transform information in an electrical format into light which is displayed on a luminescent screen (Graham and Lowe 1991, 24).

Coaxial Cable: A cable constructed from two conductors held a set distance apart by insulating material. One of the conductors forms the core of the cable whilst the other forms the outer sheath. The conductor which forms the outer sheath acts as a shield and reduces the electrical interference within the core (Graham and Lowe 1991, 30).

Direction Finding (D/F): D/F was a technique which could locate the position of a radio transmitter (Macksey 2003, 26) by plotting the bearing of the same signal from a number of different receiving stations (Syrett 2002, 165).

Electromagnetic waves: A form of radiation which can be propagated in space (Graham and Lowe 1991, 55).

Frequency: The number of complete cycles in one second (Smale 1978, 6).

Frequency Spectrum: ELECTROMAGNETIC WAVES can be grouped together in convenient classifications. These classifications take account of the wave's characteristics. For example RADIO FREQUENCY, low frequency, ultra high frequency, audio frequency (Graham and Lowe 1991, 70).

Horizontal Plane: The angle of reception of a RADIO WAVE parallel to the earth's surface.

Ionosphere: The ionosphere is comprised of a number of layers of ionised gas. These are formed at various heights above the Earth's surface from the absorption of solar radiation. The main layers, D, E, F1 and F2, extend from D, at 50km, to F2, at approximately 300km above the Earth's surface. As these layers are formed by solar radiation, the lower layers only exist during the daytime. At night, the ionisation disperses and there are no free electrons. In the upper layers, solar radiation is present 24 hours a day (Dunlop and Smith 1997, 237).

Lobe: The greatest SIGNAL strength as depicted on a RADIATION PATTERN.

Long-wave: WAVELENGTHS with a low FREQUENCY.

Multi-path transmission: SIGNALS arrive at the receiver from a number of directions as a result of 'bouncing' between the surface of the earth and the IONOSPHERE (Pierce and Posner 1980, 167).

Multiple Direction Universally Steerable Aerial System (MEDUSA): A highly-directive antenna array capable of being steered in elevation and AZIMUTH which offered improved performance on SHORT-WAVE radio channels. Such an antenna array would be able to diminish the effects of IONOSPHERIC movements experienced by fixed-direction antennae used on POINT-TO-POINT radio links (Morris and Mitchell 1959, 555).

Multiple Unit Steerable Antenna (MUSA): A 'receiving system employing sharp VERTICAL PLANE directivity, capable of being steered to meet the varying angles at which short radio waves arrive at a receiving location' (Friis and Feldman 1937, 841)

Phase: Two signals with identical FREQUENCY and AMPLITUDE can still differ if the voltage of one signal lags behind that of the other (Figure 46; Graham and Lowe 1991, 119).

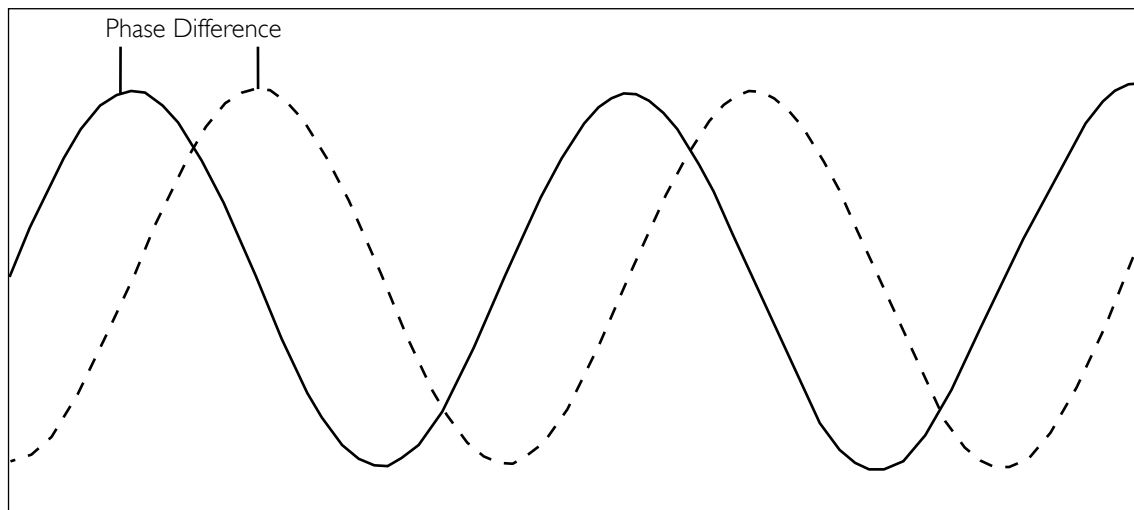


Figure 46: Phase difference between two identical signals.

Point-to-Point Communication: SIGNALS are restricted to two endpoints.

Polarisation Diversity Reception: When radio waves arrive at a receiving ANTENNA by MULTI-PATH TRANSMISSION, some of the waves will have a strong signal and others a weak signal. If a number of receiving antenna are used in several locations, it is likely that at least one antenna will receive a strong signal. Polarisation Diversity Reception combines signals from several antennae into a single output (Pierce and Posner 1980, 163).

Radiation Pattern: A graphical depiction of the relative strength of a SIGNAL transmitted from or received by an ANTENNA (University of Hawaii [www.phys.hawaii.edu/~anita/new/papers/militaryHandbook/radiapat.pdf](http://www.phys.hawaii.edu/~anita/new/papers/militaryHandbook/radiapat.pdf) accessed 18/04/2011).

Radio Frequency: The spectrum of FREQUENCIES used for radio transmissions (Graham and Lowe 1991, 129).

Radio Waves: 'A range of ELECTROMAGNETIC WAVES, in the FREQUENCY SPECTRUM from 30kHz to 3GHz, which are suitable for carrying signals across space' (Graham and Lowe 1991, 130).

Rhombic Antenna: An antenna which was widely used for transmission and reception in Point-TO-POINT COMMUNICATION (Page 1961, 478).

Signal: A transmitted electrical pulse which represents message information (Graham and Lowe 1991, 140).

Short-wave: WAVELENGTHS with a high FREQUENCY.

Signal-to-noise ratio: 'In any radio transmission, or in any communications link, a certain amount of noise is generated and is carried as background interference to the desired message signal. If the signal-to-noise ratio is high, then the message is unlikely to be impaired; if it is low, the signal may well be severely impaired' (Graham and Lowe 1991,

142).

Single Sideband: Low FREQUENCY (LONG-WAVE) signals require large amounts of energy to transmit over long distances. One method to overcome this was AMPLITUDE MODULATION (Graham and Lowe 1991, 99). However, a CARRIER WAVE modulated at a single frequency produces three SIGNALS: 'the unmodulated CARRIER and two associated steady frequencies spaced on either side of the carrier frequency of modulation' (Figure 45) (Graham and Lowe 1991, 142).

Amplitude modulation is wasteful of BANDWIDTH because it requires a 'transmission bandwidth equal to twice the message bandwidth. ... [T]he upper and lower sidebands are uniquely related to each other by virtue of their symmetry about the carrier frequency ... This means that insofar as the transmission of information is concerned, only one sideband is necessary, and if the carrier and the other sideband are suppressed at the transmitter, no information is lost' (Haykin 1978, 267). Transmission of one sideband is referred to as single sideband (Haykin 1978, 267).

Sun-Spot: One of the dark patches on the sun's surface which can change shape and size and is associated with powerful ELECTROMAGNETIC radiation (Allen 1990, 1223).

Telegraph: A means of transmitting alphanumerical or electrical signals between two locations (Graham and Lowe 1991, 154).

Telephone: A means of transmitting audio FREQUENCIES (Graham and Lowe 1991, 154).

Vertical Plane: The angle of reception of a RADIO WAVE perpendicular to the earth's surface.

Wavelength: ELECTROMAGNETIC WAVES travel through space at a speed of  $3 \times 10^8 \text{ms}^{-1}$ . The wavelength of an electromagnetic signal is obtained by dividing  $3 \times 10^8 \text{ms}^{-1}$  by the signal frequency in cycles per second (Hertz) (Graham and Lowe 1991, 176-7).



## REFERENCES

### Primary Sources

BT Archives: *Cooling Radio Station Folder*

BT Archives: POST 33/4245 *Wireless Telephony*

BT Archives: POST 33/5313 *Transatlantic Radiotelephone Service*

BT Archives: TCB 2/102 *Cooling Radio Station 1936-44*

TNA: PRO CAB 116/32: *Security of radio telephone transmission 1942-5*

TNA: PRO FT 17/1: *High Halstow Site history: species lists, reports on visits, maps 1950-7*

TNA: PRO FT 17/2: *High Halstow Site history: species lists, reports on visits, maps 1958-61*

TNA: PRO HW 8/98: *The Naval 'Y' Service in Wartime 1939-1945*

TNA: PRO RAIL 1188/170: *Cliffe Airport 1943-6*

### Secondary Sources

Allen, R (ed) 1990 *The Concise Oxford Dictionary* Clarendon Press, Oxford

Angwin, A 1950 'Developments in Cables and Wireless technique for Service Communications' in *The RUSI Journal* **95**, 436-47

Beesly, P 2000 *Very Special Intelligence: The Story of the Admiralty's Operational Intelligence Centre 1939-1945* Chatham Publishing, London

Booth, C 1949 'The Receiving System at Cooling Radio Station' in *The Post Office Electrical Engineering Journal* **42**, 84-89

Bown, R 1937 'Transoceanic Radiotelephone Development' in *Proceedings of the Institute of Radio Engineers* **25 9**, 1124-1135

Bray, J 2002 *Innovation and the Communication Revolution: from the Victorian pioneers to broadband internet* The Institute of Electrical Engineers, London

Dunlop, J and Smith, D 1997 *Telecommunications Engineering* Chapman and Hall, London

English Heritage 2007 *Understanding the Archaeology of Landscapes: a guide to good recording practice* English Heritage, Swindon

English Heritage 2010 *The National Heritage Protection Plan: Interim version – December*

2010 English Heritage, Unpublished

Feldman, C 1939 'Deviations of Short Radio Waves from the London-New York Great-Circle Path' in *Proceedings of the Institute of Radio Engineers* **27 10**, 635-45

Flight 1943 'Thinking of the Future' in *Flight* 29 July 1943, 115

Friis, H and Feldman, C 1937 'A Multiple Unit Steerable Antenna for Short-Wave Reception' in *Proceedings of the Institute of Radio Engineers* **25 7**, 841-917

Graham, J and Lowe, S 1991 *Dictionary of Telecommunications* Facts on File, New York

Gregory, D 2010 *The CSA Building, Kent: an analytical earthwork and building survey: Project Design* English Heritage, Unpublished

Hall, L, Lloyd, H, Richards, C 1940 'The Localisation of Small Leaks in the Underground Transmission Line System at Cooling Radio Station' in *Post Office Electrical Engineers Journal* **32**, 138-41

Hawkins, P 1995 'The Development of Short Wave Radio Telecommunications in the 1920s and 30s' in *International Conference on 100 years of Radio* IEE Conference Publication **411**, 147-52

Hawkins, P 2004 'HF Telecommunications, what happened between Poldhu and Telstar' in *2003 Ninth International Conference on HF Radio Systems and Techniques* IEE Conference Publication **493**, 1-6

Hay, I 1946 *The Post Office went to War* His Majesty's Stationery Office, London

Haykin, S 1978 *Communication Systems* John Wiley and Sons, United States of America

Macksey, K 2003 *The Searchers: How Radio Interception Changed the Course of both World Wars* Cassell, London

Morris, D and Mitchell, G 1959 'A Multiple-Direction Universally-Steerable Aerial System for H.F. Operation' in *Proceedings of the Institute of Electrical Engineers - Part B: Electronic and Communication Engineering* **106 30**, 555-8

Morris, D, Mitchell, G, May, E, Hughes, C, and Dagleish, D 1963 'An experimental multiple-direction universally steerable aerial system for h.f. reception' in *Proceedings of the Institute of Electrical Engineers* **110 9**, 1569-82

Mumford, A 1945 'Radio Section: Chairman's Address' in *Journal of the Institution of Electrical Engineers - Part I: General* **93 61**, 41-50

Mumford, A 1947 'Long-Distance Point-to-Point Communication' in *Journal of the Institution of Electrical Engineers - Part IIIA: Radiocommunication* **94 11**, 23-43

Nicholls, J 2000 *England Needs You: The Story of Beaumanor Y Station World War Two* Joan Nicholls, Cheam

Page, H 1961 'Aerials: a review of progress' in *Proceedings of the Institute for Electrical Engineers Part B* **108 41**, 473-89

Pierce, J and Posner, E 1980 *Introduction to Communication Science and Systems* Plenum Press, New York

Polkinghorn, F 1940 'A Single Sideband Musa Receiving System for Commercial Operation on Transatlantic Radiotelephone Circuits' in *Proceedings of the Institute of Radio Engineers* **28 4**, 157-70

Smale, P 1978 *Telecommunication Systems* Pitman, London

Stretson, H 1947 'Sunspots and Radio' in *Astronomical Society of the Pacific Leaflets* **5**, 209-16

Syrett, D 2002 'The infrastructure of communications intelligence: the Allied D/F network and the Battle of the Atlantic' in *Intelligence and National Security* **17 3**, 163-72

The Morton Partnership Ltd. 2010 *Structural assessment of Cooling Radio Station, Cooling, Kent, ME3 8DS* The Morton Partnership Ltd, Unpublished

Turner, F 2000 *Cooling Radio Station* FR Turner, Gravesend

## **Aerial Photographs**

NMR RAF/I06G/UK/I444 400I 1-MAY-1946 English Heritage (NMR) RAF Photography

NMR RAF/540/496 F20 419I 12-MAY-195I English Heritage (NMR) RAF Photography

NMR RAF/82/713 695 6-FEB-1953 English Heritage (NMR) RAF Photograph

NMR RAF/58/4137 F96 F43 64 9-FEB196I English Heritage (NMR) RAF Photograph

NMR RAF/58/4646 F96 F43 347 28-AUG-196I English Heritage (NMR) RAF Photograph

NMR RAF/58/4646 F96 F43 346 28-AUG-196I English Heritage (NMR) RAF Photograph

NMR OS/7350 087 17-AUG-1978 © Crown copyright. Ordnance Survey

## **Film**

Jennings, H 1938 *Speaking from America* GPO Film Unit

## Websites

BBC [www.bbc.co.uk/ww2peopleswar/stories/25/a8259825.shtml](http://www.bbc.co.uk/ww2peopleswar/stories/25/a8259825.shtml) accessed 26/07/2010

University of Hawaii [www.phys.hawaii.edu/~anita/new/papers/militaryHandbook/radiapat.pdf](http://www.phys.hawaii.edu/~anita/new/papers/militaryHandbook/radiapat.pdf)  
accessed 18/04/2011

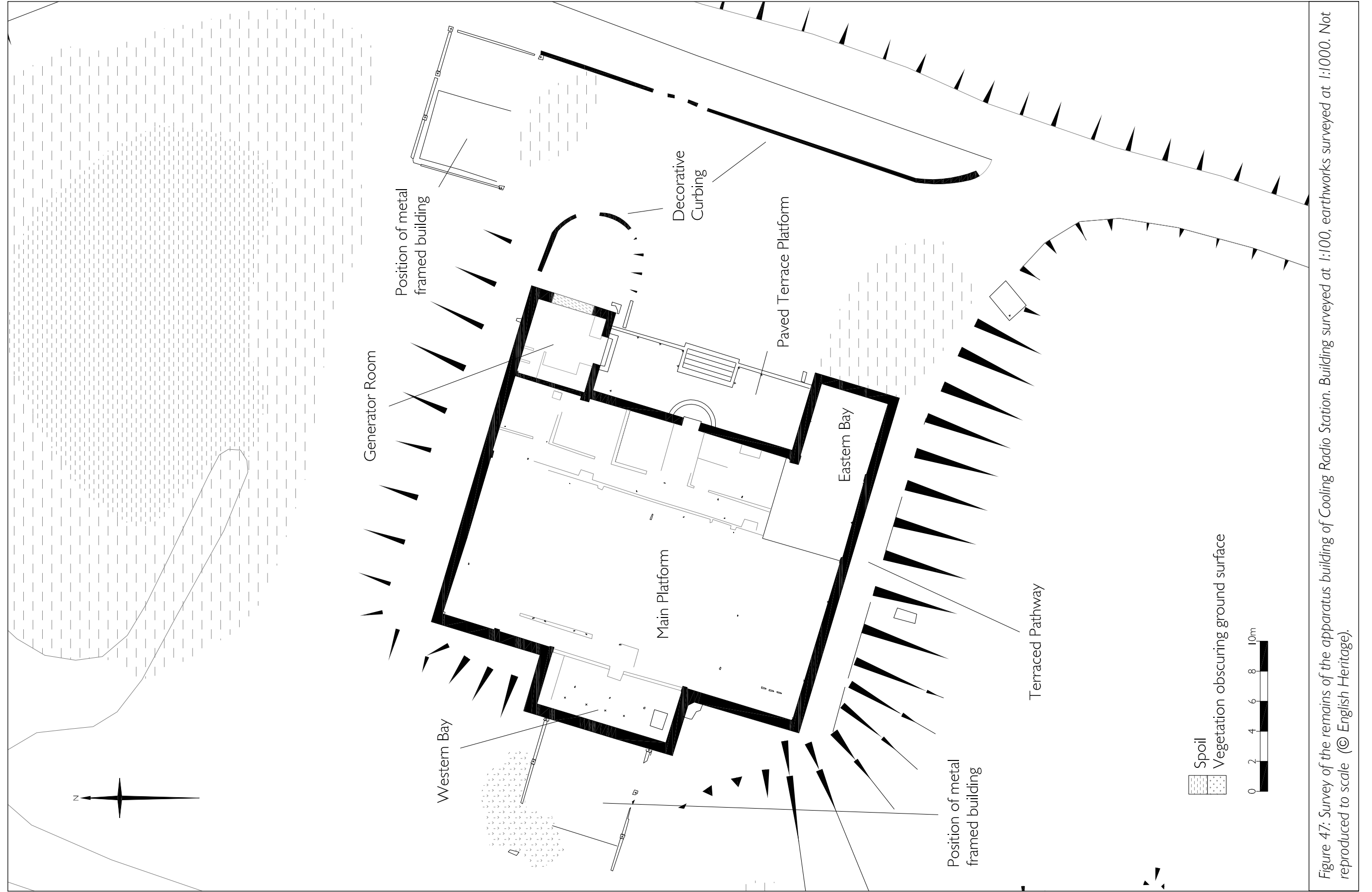


Figure 47: Survey of the remains of the apparatus building of Cooling Radio Station. Building surveyed at 1:100, earthworks surveyed at 1:1000. Not reproduced to scale (© English Heritage).

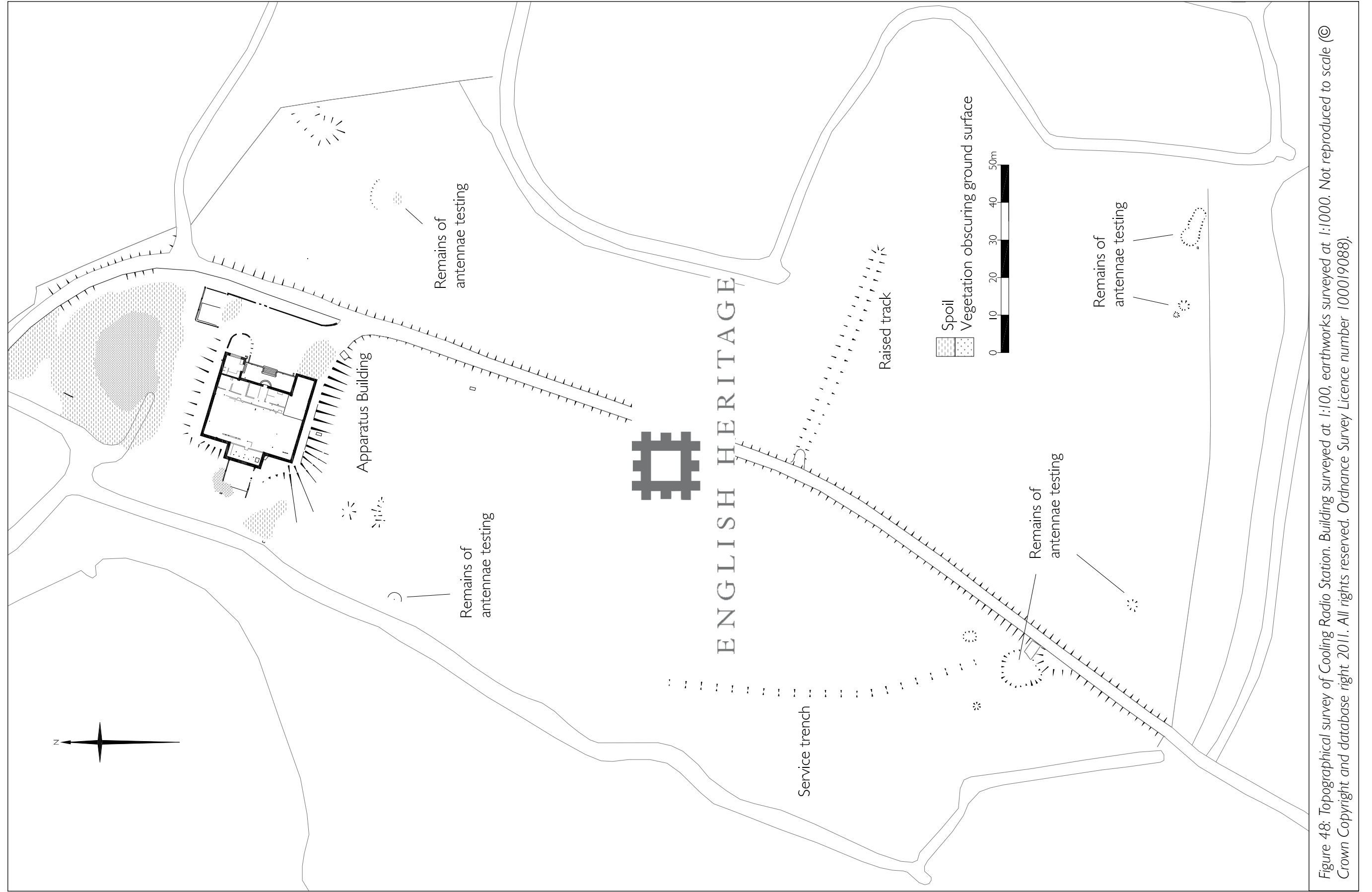


Figure 48: Topographical survey of Cooling Radio Station. Building surveyed at 1:100, earthworks surveyed at 1:1000. Not reproduced to scale (© Crown Copyright and database right 2011. All rights reserved. Ordnance Survey Licence number 100019088).



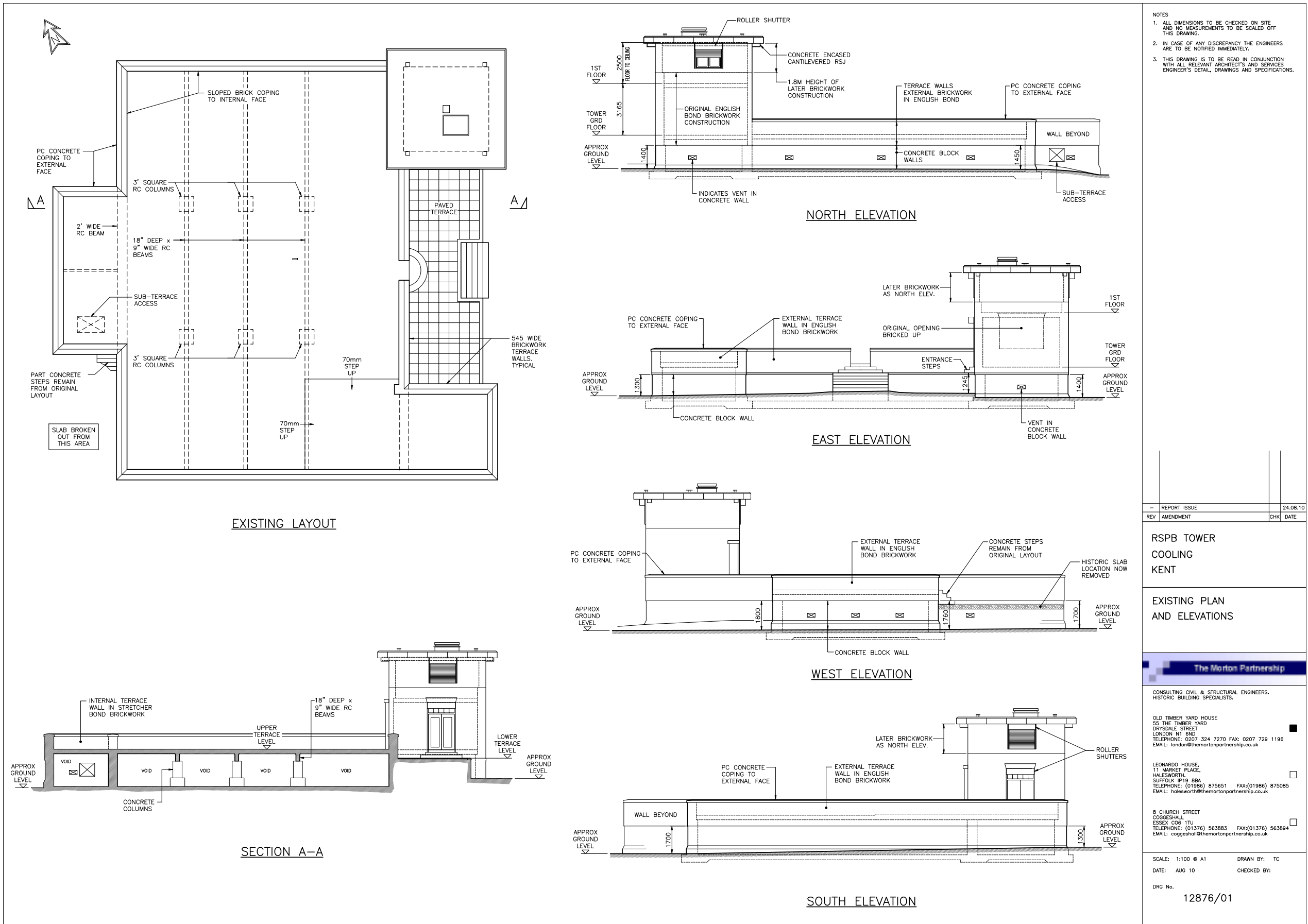
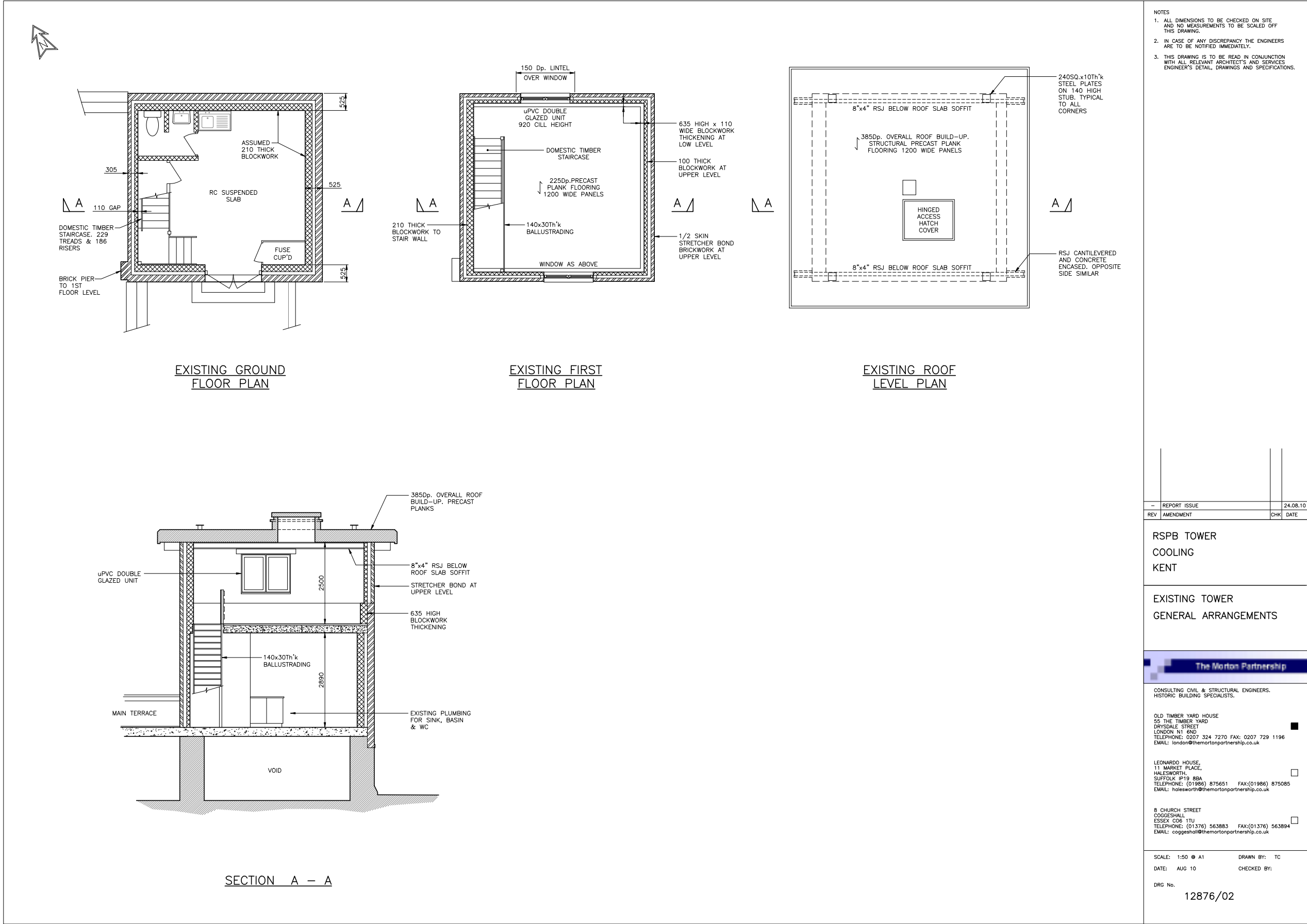


Figure 50: Structural survey of the remains of the apparatus building (© RSPB 2011 courtesy of RSPB).







## ENGLISH HERITAGE RESEARCH DEPARTMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.

The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:

- \* Aerial Survey and Investigation
- \* Archaeological Projects (excavation)
- \* Archaeological Science
- \* Archaeological Survey and Investigation (landscape analysis)
- \* Architectural Investigation
- \* Imaging, Graphics and Survey (including measured and metric survey, and photography)
- \* Survey of London

The Research Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support outreach and education activities and build these in to our projects and programmes wherever possible.

We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities. A full list of Research Department Reports, with abstracts and information on how to obtain copies, may be found on [www.english-heritage.org.uk/researchreports](http://www.english-heritage.org.uk/researchreports)

For further information visit [www.english-heritage.org.uk](http://www.english-heritage.org.uk)

