Tests of C.R.D.F. on transmissions from aircraft: five test flights using long wave marine C.R.D.F. with Bellini-Tosi and Adcock aerials : June-November 1938

National Research Council of Canada

NATIONAL RESEARCH COUNCIL OF CANADA

TESTS OF C. R. D. F. ON TRANSMISSIONS FROM AIRCRAFT

OTTAWA

MARCH, 1939

ANALYZED

NATIONAL RESEARCH COUNCIL OF CANADA

TESTS OF C. R. D. F. ON TRANSMISSIONS FROM AIRCRAFT

FIVE TEST FLIGHTS USING LONG WAVE MARINE C. R. D. F.

WITH BELLINI - TOSI AND ADCOCK AERIALS

JUNE - NOVEMBER 1938

OTTAWA

MARCH, 1939

FIRST TEST FLIGHT

Date of Flight

Thursday, 24 June, 1938, at 14 hours E.D.T.

Object

To omit signals from plane using long trailing aerial in order to determine how aeroplane effect appears on the cathode ray tube and hence to deduce how night errors will show up on tube.

Apparatus

(a) Aeroplane, Fairchild 71, No. 643 of R.C.A.F.; portable 40-watt transmitter and 240 feet trailing aerial.

(b) Marine C.R.D.F. using 110 kc. to deflect spot. Bellini-Tosi loop, 66 feet high, approximately 146 feet across base. Earth system 16 radials, each 150 feet long, bonded along circumference, buried about 8 inches below soil, no deep rods to connect to wet soil below sandy top soil. Temporary connections only from loops to input arrangement inside trailer.

Procedure

Plane took off at 1357 hours and transmitter started at 1401 hours. Flight from Rockcliffe Airport to field station more or less in straight line, altitude about 1000 feet.

On reaching D.F.mast flat climbing turns were performed until an altitude of 3,500 feet was reached. Then proceeded westward in straight line until over the Hunt Club, three climbing turns here, final altitude 6000 feet, which was maintained for the rest of the flight. Proceeded west to junction of road and C.N.R. track where three circles made. Flew over junction of Jock and Rideau Rivers, three turns here, thence about due east; over Manotick Station three turns made. Flying to Greely three more turns made and then in a line to Pipervillo Station where three more turns made. Final three circles were made over C.N.R. tracks about 3/8 of a mile east of Hawthorne and then plane returned to Rockcliffe Airport.

Characteristic signals were emitted at each turn and observed at the D.F.station. It was found to be difficult however, to read the signals on the cathode ray tube, probably largely due to inexperience.

Observations

A good bearing of 350° was noted on the ground when the plane was approaching. Generally speaking the only bearings noted at the D.F.station were those taken when the plane flies directly towards or away from the receiving aerial, all other bearings show "night effect" or more properly speaking "aeroplane effect". This is in accordance with other observers and indicates that the type of receiving aerial is inadequate for direction finding purposes of aircraft when the altitude is comparable with the distance.

When the trailing aerial is in any direction other than pointing towards or away from the receiving aerial, the elliptical patterns show on the cathode ray tube, giving large errors of bearing, amounting to 90° in some cases.

When the plane is circling (radius about 1/2 mile, distances roughly between 5 and 7 miles, altitude generally 6000 feet) then the bearings rotated through 360° and in some cases give two complete revolutions for each turn of the plane.

For detailed observations see Appendix I.

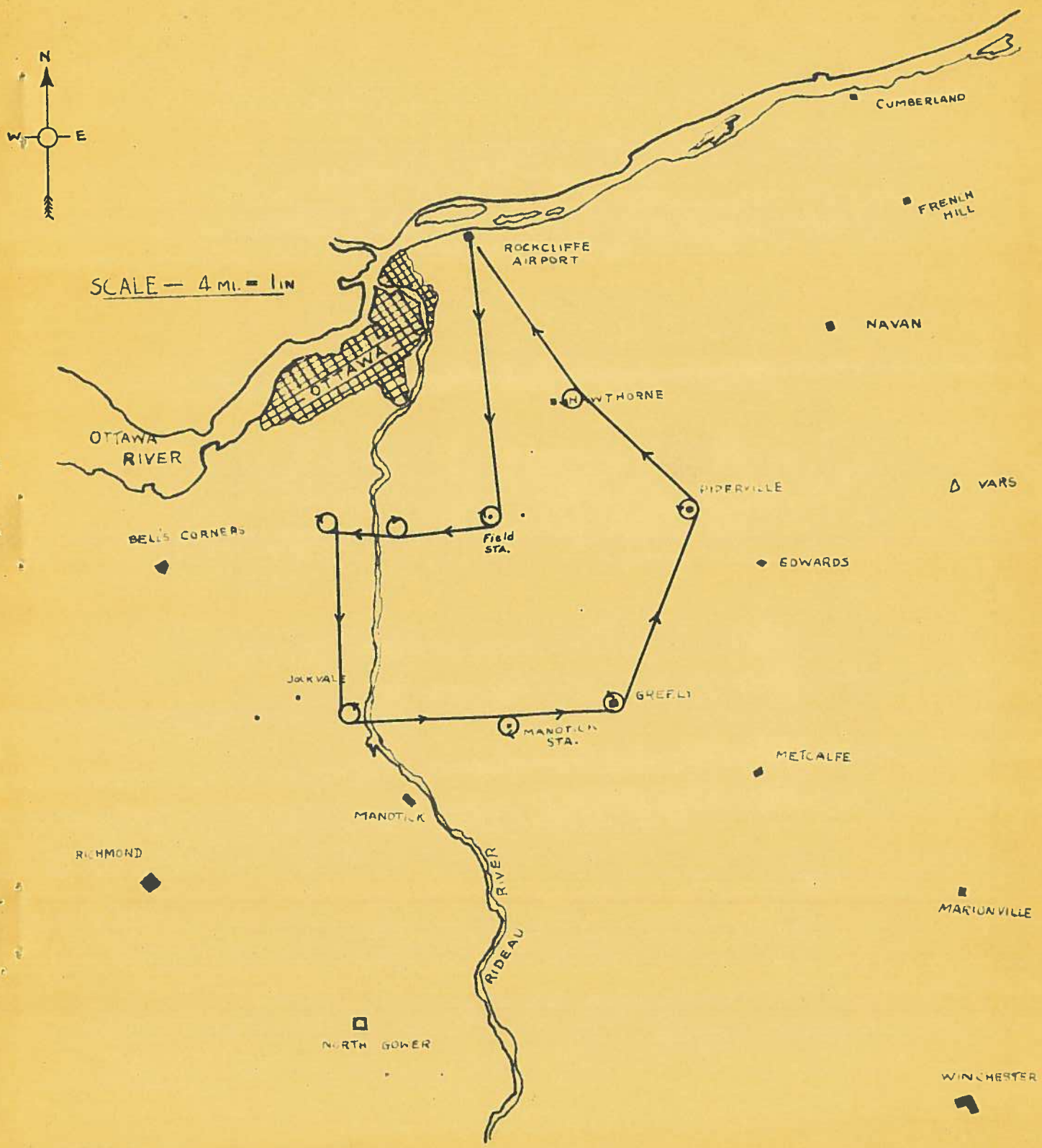
Conclusions

1. The Bellini-Tosi loop system is unfitted for this work.

2. Even small amounts of night error turn the straight line bearing into an ellipse on the cathode ray tube.

7 July, 1938.

FIRST TEST FLIGHT



SECOND TEST FLIGHT

Date of Flight

Monday, 4 July, 1938, at 1448 hours, E.D.T.

Object

To determine variation of aeroplane effect as it appears on cathode ray tube for aeroplane flight at different altitudes.

Apparatus

As for first test flight.

Procedure

Plane took off at 1442 hours and transmitter started almost immediately. Plane flew straight to Bellini-Tosi field station at an altitude of about 1000 feet. Two circular turns were made around the mast and plane then proceeded at an altitude of about 1000 feet to point G on the map, roughly ten miles from the observing site. Course was then due south to point J (on Winchester sheet of map). At both G and J points two circular turns were made. From J the plane was supposed to fly in a straight line to the Bellini-mast again but due to cross wind drifted slightly and came in towards the receiving aerial in a curved line. Climbing turns were performed around the mast until an altitude of about 6000 feet was reached. Plane then flew due south ten miles, made three complete circles around point R and proceeded six miles due east to point M. Three circles were made here and plane then flew in an approximately straight line towards receiving site until it reached the point Q where two circles were made. The course then followed a north-easterly direction until point W was reached, where two turns were made. Plane then flew straight towards the receiving aerial, turned and flew straight towards the airport. The flight ended at 1603 hours.

Observations

On the ground most bearings are considerably in error. The three cases (at 1531, 1540, 1559 hours) where good bearings were obtained all fall into the class in which the receiving aerial and transmitting aerial are in the plane of propagation, that is, the aeroplane is flying directly towards, or away from the receiving site. Two other cases when the plane was flying in this way do not give good bearings however. It should be remembered that

the difficulties of obtaining good bearings in the course of this test are almost certainly those of propagation and not instrumental difficulties of the direction finder.

The most disconcerting feature of the whole test is that at 1509 hours good straight line indications were obtained but the bearing observed was evidently quite wrong. It seems probable that when a plane is flying at greater distances from the receiving site that this effect would disappear but the point has not been tested and we are confining our attention for plane-to-ground D.F.work, to the installation of an Adcock serial system. To obtain good bearings we expect to discontinue the use of a long trailing aerial in a plane and I understand that the experience of the air-line companies also confirms this point. The long trailing aerial was used in these test flights in order to give the maximum amount of abnormally polarized waves because our object was the observation of aeroplane effect and night effect, not the accurate determination of good bearings.

When the aeroplane was making a complete turn at any point the bearings of the plane rotated 360^{o}. This is undoubtedly due to the effect of a long trailing aerial and to the type of polarized waves being received. In general, it would be impossible to get any idea of the position or direction of the aeroplane, using a Bellini loop system, when the aeroplane is flying so close to the receiving site.

Details of the observations are given in Appendix 2. Just what degree of accuracy was obtained it would be impossible to say at present because the position of the plane was not known with sufficient precision. Changes observed on the cathode ray tube while the plane was turning circles would have been too rapid to measure with any other type of direction finder.

A point incidental to this particular test is that several radio range stations for aircraft were tuned in. In general these give good indications on the receiver but some of the transmitters using loop aerials have different directions when using differently oriented loops.

Conclusions

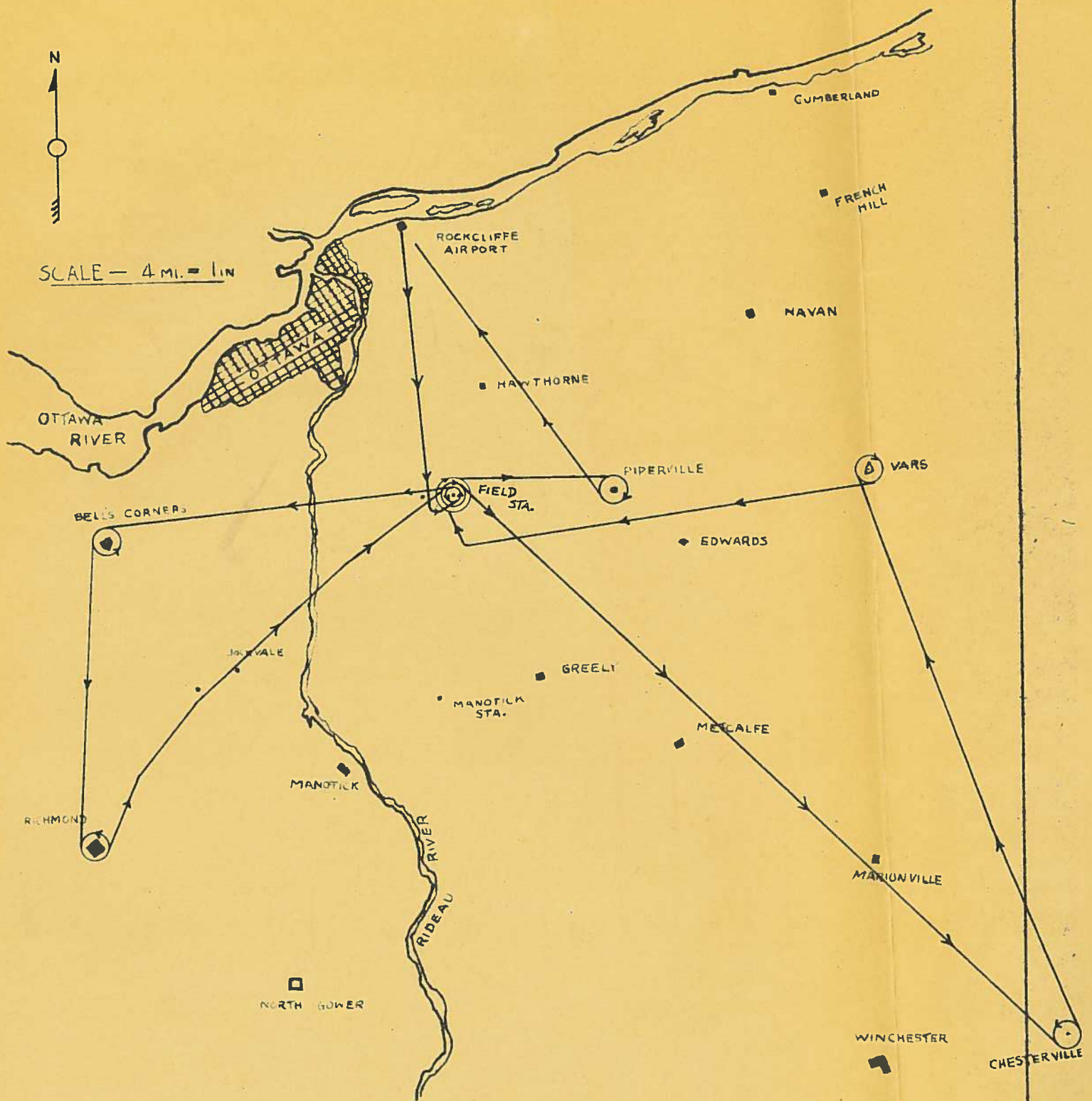
1. The amount of night effect observed varies with location and altitude of the aeroplane and is shown by

an ellipse of varying sizes on the cathode ray tube.

2. The cathode ray direction finder will follow variations in the state of polarization of the received signal transmitted from the aeroplane using a long trailing aerial. The rapidity of the change in apparent direction of the received signal when an aeroplane is circling at an altitude high relative to the distance from the receiving aerial is so great that it can be followed only by some type of direction finder such as the one used in the present experiment.

3. Some type of aerial system which eliminates night error must be used to obtain good bearings from an aeroplane flying close to the receiving set. It seems likely that the elliptical patterns on the cathode ray tube occur when improper minima would be detected with the ordinary aural null type of direction finder but it was not possible during this flight test to make any observations on this point as the Marconi direction finder was not in circuit at the time.

THIRD TEST FLIGHT



THIRD TEST FLIGHT

Date of Flight

Tuesday, 27th September, 1938, at 1510 hours, E.S.T.

Object

To determine the amount of "aeroplane effect" and "night error" visible on a cathode ray direction finder where used with an Adcock aerial system.

Apparatus

The transmitter used (NRL-P-1169) had a nominal power output of 30 watts which is somewhat smaller than the one used for the first two flights (NRL-P-1072). The same aeroplane (viz. Fairchild No.643) and long trailing aerial were used. The receivers were those previously used at the Bellini-Tosi site, that is the CRDF built in the laboratories and the Marconi MDF4.

The Adcock aerial system was modeled after that described by Barfield (Journ. I.E.E. vol.81, p.676, 1937). It should be regarded as being in the preliminary stage and will undoubtedly require some minor modifications. Construction was started in September and the aerial has been in operation only since Friday, 23 September, 1938. The adjustment of the aerial is such that good bearings are obtained from Albany, N.Y. 365 kc., Syracuse, N.Y., 350 kc., and Elmira, N.Y., 385 kc. These bearings are not exactly the same as those observed at the Bellini aerial some two miles distant but no attempt was made to reduce the observed bearings to a true bearing because we have not yet calibrated the site errors of the Adcock system. It is undesirable to take time to do so until we have the aerial system in its final form. No night error was observed in the radio range stations and the bearing at night was the same as that during the day. It was concluded therefore that the system was working well enough to make a trial flight.

At present the aerial consists of four vertical wires strung from small arms at the tops of 60 foot wooden poles and a similar fifth wire in the centre of the square formed by the first four poles. The centre wire is to give sense indication but was disregarded for the present experiments. The diagonals of the square are 100 m. and are oriented N-S and E-W to within a few minutes of arc, as checked by stellar observations. The aerial pick-up

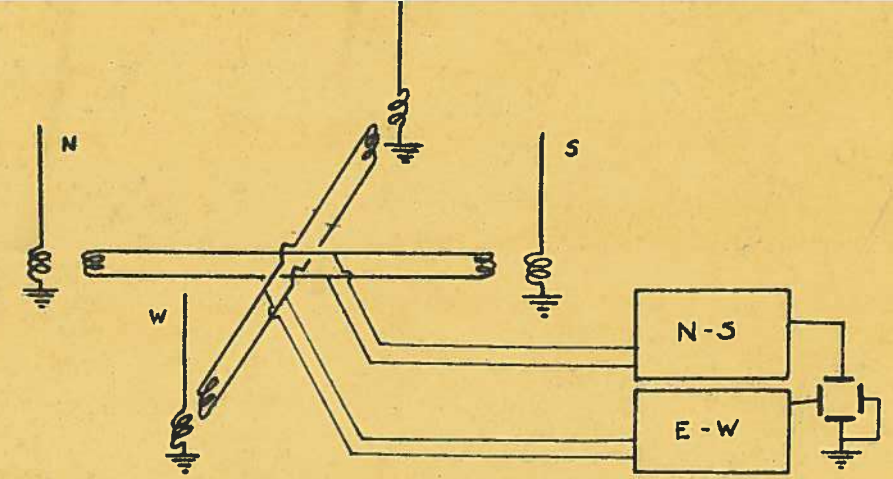


FIG. I

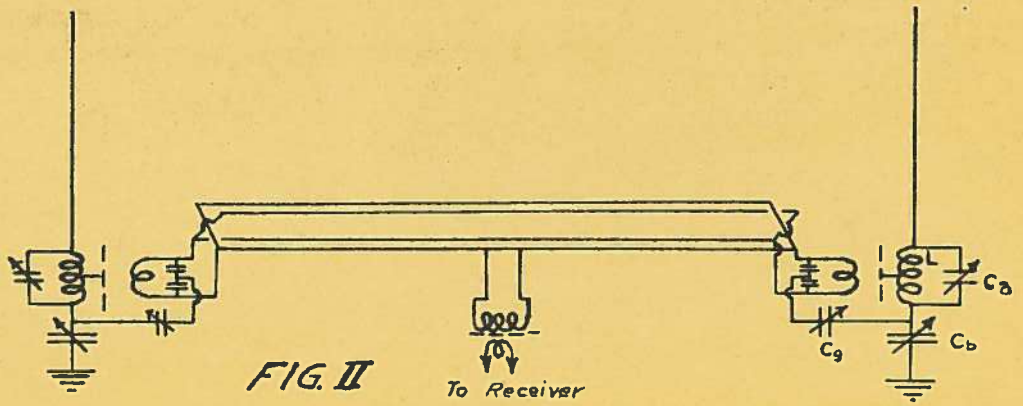


FIG. II

can be increased by using a larger number of vertical wires at each pole, as previously described by Barfield. It was felt the additional wires for increased pick-up might be a little more troublesome to install initially and were not used because our primary concern was the receiver rather than the erection of the most efficient aerial. The ground system consists of a set of sixteen, seventy-five foot radial wires at each of the five poles.

The arrangement is shown schematically in Figs. I and II. Each pair of verticals, taking the place of one of the two fixed loops, is connected to one receiver of the cathode ray direction finder, so that a signal coming from

the North-South direction will deflect the spot vertically and one from the East-West will deflect it horizontally. A signal from any other direction will deflect the spot into a line making an angle with the vertical indicating the direction of arrival of the signal in the same manner as when using loop aerials.

When a radiogoniometer is used the two pairs of field coils are, of course, connected to the two pairs of fixed verticals and the operation of finding a minimum is the same as when using loop aerials.

The vertical aerials are connected to the input transformers in the receivers by a four wire 300 ohm transmission line as shown in Fig.II. This is supported on wooden poles 27 feet apart, 8 feet above the ground, using ordinary telephone insulators. No change is noted in the pattern on the cathode ray tube if one or two of the wires in the four wire system is moved four inches at the centre of the small span. A strong wind will only rarely move these wires as much as an inch, so that the line appears to be satisfactory. The two transmission lines from N-S and E-W aerials were installed as symmetrically as possible but at the centre of the system the E-W line is one foot below the N-S line.

The antenna loading circuits (L, Ca) are tuned to a frequency below the normal range of 300 to 400 kc, within which it was desired to operate. This minimizes the difficulties that might be encountered if resonance occurred at an operating frequency. A gain in signal strength across the whole band of the order of 10 D B is realized by tuning the transmission lines to a frequency just above 400 kc. This is accomplished by connecting .005 mfd fixed condensers with .001 mfd adjustable mica padders across the lines.

The procedure used in balancing the system was to set the condensers Cb to about the same capacity as that of the aerials to ground (approx. 120 mmf) so that the centre-tap of L is at true ground potential. Condensers Cg had been included to balance out any injection of a signal into the aerials by voltages induced in the transmission lines by a horizontal component, but no satisfactory method was found of adjusting these because it was not found possible to produce a horizontal voltage in the transmission lines.

The N-S aerials are now adjusted on signal frequency by injecting a signal into the west aerial and adjusting condensers Ca on the N-S aerials for zero signal into the receiver. Similarly the E-W aerials are adjusted on the same frequency. With this method of adjustment considerable trouble was experienced in arriving at an adjustment of the aerials that produced signals in the receiver of the same phase from the N-S and E-W systems.

Observations

The flight was made over a course very similar to those of the first two tests. The aeroplane took off at 1511 hours, the transmitter being started about two or three minutes later. (The notes made during the flight are given in Table III appended to these reports.)

The plane flew to the receiving site via the radio range station, which is located south of our own field, circled once around the Adcock aerial and then proceeded to Bell's Corners. After one circle there, the plane flew to Richmond, circled and returned to the receiving site. The route then was intended to be straight to Winchester, but due to an easterly drift the plane went off course somewhat and circled twice over Chesterville. From Chesterville the plane went to Vars where it circled twice and then flew towards the receiving site. The plane drifted somewhat south of a straight line course and passed between Edwards and Piperville. The plane circled over the receiving site and made a short flight to Piperville, circled there and then headed for the airport. (During this short flight to Piperville the observations were made with the MDF4 receiver.) The altitude of the plane was maintained between 1500 and 1800 feet. Visability was poor.

Generally speaking the bearings on the cathode ray tube did not show up as straight lines but were elliptical having a major axis about eight inches long and minor axes varying from 1/8" to 1/4". In a few extreme cases the minor axis was as large as 3/4" and at other times the ellipse disappeared completely in certain directions. When the bearing was elliptical, however, the major axis gave a very good indication of the true bearing of the plane, as far as can be determined from our relatively rough observations of the aeroplane's position. It is believed that the aerial system requires further balancing to eliminate these loops.

However, the results so far are encouraging because when the plane made the circles over Bell's Corners, Richmond, Chesterville and Vars the bearing varied a few degrees but showed no change in shape while the plane was making the turn. That is to say, if the bearings were straight lines for points along the route immediately preceding the turn then the bearings remained straight lines while the aeroplane flew in circles of radius roughly half a mile; this is the case for Vars, which being the point nearest to the receiving site, would be expected to give the greatest amount of downcoming wave. At Bell's Corners and Richmond the variation in bearing was small, at the former point because the aeroplane flew in a very small circle. The bearings to Richmond and Chesterville were slightly elliptical, showing in fact, the maximum minor axes at these points. When the circles were made the ellipse did not alter appreciably but simply showed a variation in the direction of the major axis, about $\pm$ 1/2° and $\pm$ 1° respectively for the two points.

If the plane had flown in circles of half mile radius at each of the turning points the expected variation of bearing would be $\pm$ 3° at Bell's Corners, $\pm$ 2° at Richmond, $\pm$ 1° at Chesterville, and $\pm$ 2 1/2° at Vars. (The variation would be $\pm$ 1° at Bell's Corners for a circle of radius approximately 1/4 mile). These agree as well as can be expected with the observations because the exact radius of the circle flown at any given point is not known.

For the rest of the course the bearings agree, to within the limits of experimental error, with those that would be expected and it is gratifying to get such good agreement considering the short time available for the adjustment of the aerials. Of course, no corrections for the site errors are available yet and more precise work is required to determine the limits of accuracy of the apparatus.

In the notes, at 1540 hours, the remark "took down transmitter aerial" appears. This refers to a short piece of #18 wire, about twenty feet long, which was fastened vertically to the centre pole of the Adcock system and used as the aerial for a 20 watt short-wave transmitter for communication to the laboratory. It appeared to have no effect on the bearing.

At 1550 hours the remark "changed condenser" refers to the fact that one condenser across the feeder lines was found disconnected. Putting this condenser back in place changed the bearing from 113° to 130°, the latter being

more nearly correct. It is uncertain when this break in the connections occurred but judging from the agreement between observed and true bearings it probably occurred at 1524 hours when one of the observers went outside the trailer to note the position of the plane circling overhead.

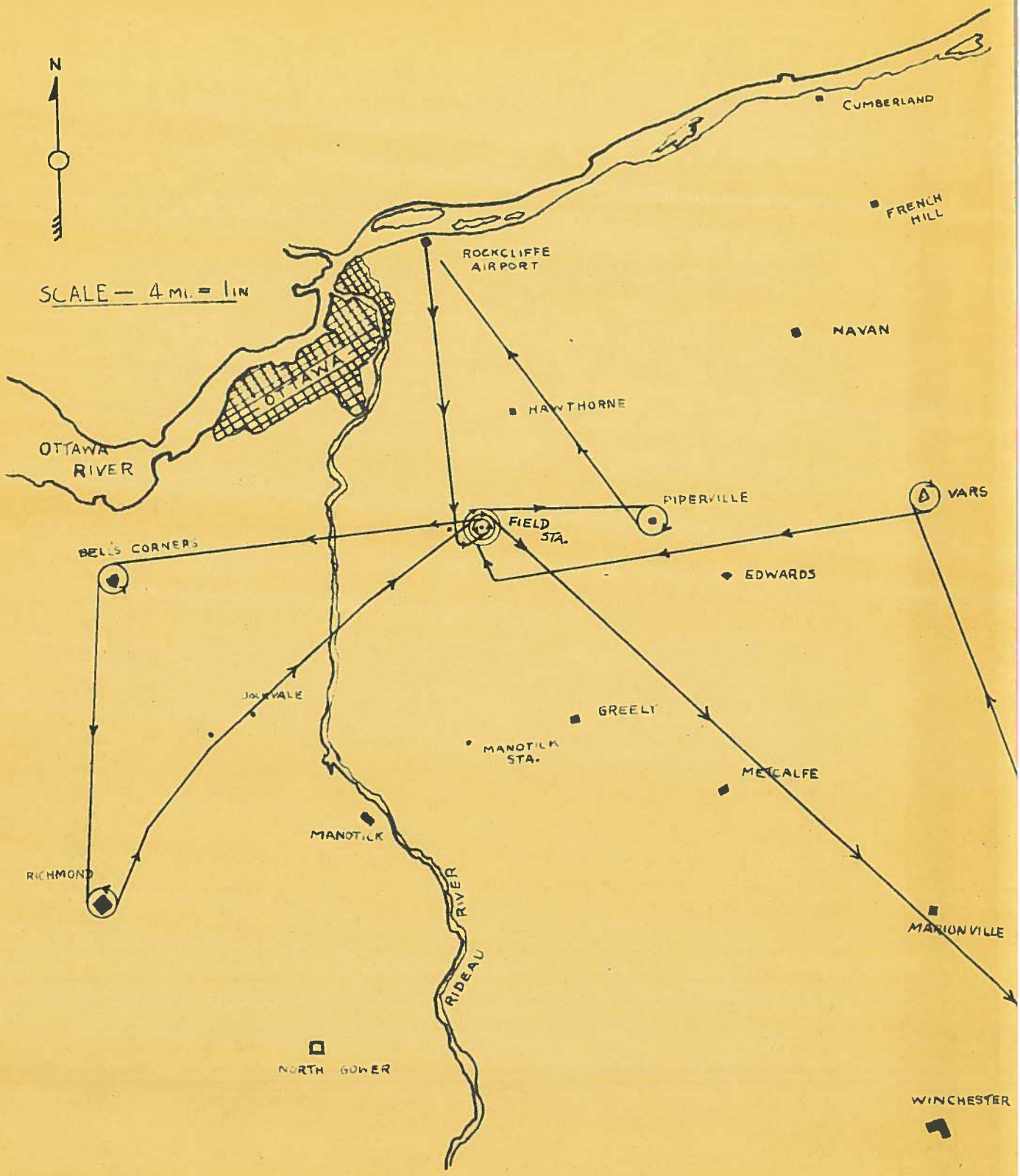
At the end of the flight, i.e., after 1622 hours, bearings were taken with the Marconi MDF4 receiver. When the plane was close to the Adcock aerial it was difficult to get a sharp minimum and, of course, no minimum was possible as the plane passed directly overhead. (When using the cathode ray direction finder and the plane passes directly overhead the bearing degenerates into a circle). With the transmitter a little farther away, it is possible to get a sharp minimum. The balancing adjustment of this receiver depends on having a signal from the mid-point of a Bellini-Tosi system. During the flight this input was provided by using a short piece of wire, six feet long, as an aerial but the pick-up was evidently insufficient for the purpose. From the behaviour of the two receivers on the Bellini-Tosi loops, we are confident that a higher percentage of good minima would be obtained from the MDF4 had time been available for correct initial adjustment to provide a wider range for the balancing unit. The twelve minutes observations with the MDF4 gave us only an indication of its behaviour. It is, of course, easier and much quicker to obtain the bearing of the aeroplane using a cathode ray direction finder.

Conclusions

The Adcock aerial system eliminates night error but some further work on the system is required to get perfect bearings from aircraft. The bearings at present are satisfactory, compared to the complete absence of bearings from a loop aerial system, but there is still room for improvement in the aerial itself.

The cathode ray direction finder is satisfactory for obtaining bearings of aircraft in flight when used in conjunction with an Adcock aerial. It is more rapid in operation than a receiver using a goniometer and it gives a clear mental picture of the situation.

THIRD TEST FLIGHT



FOURTH TEST FLIGHT

Date of Flight

Thursday, 3rd November, 1938.

Object

To repeat the observations of 27 September.

Apparatus

The transmitter trailing aerial and aeroplane, and the Adcock receiving aerial on the ground remained as before. The MDF4 was not altered but in the interval the cathode ray direction finder had been taken back to the laboratory. The receiver is essentially the same as before but its tuning range has been restricted to cover only two narrow bands, viz., 350 to 400 kc. and285 to 315 kc. Tuning is now single dial with a small trimmer condenser in the N-S radio frequency tuned circuit. It was found that the tuning of the sense receiver was not sufficiently critical to use trimmers in it. The one trimmer in the N-S set permits accurate tuning of the whole receiver. One other trimmer adjustment is used to compemsate for any change in the relative gains of the N-S and E-W receivers. An audio frequency unit has been added which can be switched to any one of the three intermediate frequency amplifiers. A photograph of the complete CRDF receiver in its present form appears at the end of these reports.

Procedure and Observations

It was decided to try to adjust the Adcock aerial using the signal from the aeroplane. For this the plane was kept flying in a circle with the Adcock aerial as centre and radius about two miles, the altitude being kept constant at about 1000 feet. As the plane circled the field it would be in line with, say, the N-S aerial. The input from this pair of aerials was then removed by short circuiting the appropriate feeder lines. It was assumed that any remaining signal in the E-W receiver was due to lack of proper adjustment in the tuning condensers Ca (see Fig.II in report of previous flight).

In this somewhat rough and ready fashion the balancing was improved by a method of successive approximation. Although requiring still further adjustment the indications of bearing were improved making for easier observation.

After an hour spent in balancing aerials in this way the plane proceeded on its course from the field station to Bell's Corners, to Richmond, to Metcalfe, and thence to the Ottawa River which was reached at a point just east of Cumberland. There was a lot of smoke and visibility was poor throughout the flight.

It was particularly noted on this flight that the bearings of the plane taken on the ground were good until it was very close to the receiver, to within three hundred yards about.

The flight confirmed the results of the third test, that it is possible to get good bearings on the aircraft and that the changes in polarization which occur as the plane made a small circle at each of the above places, do not affect the receiver, and show only as a small variation of bearing.

The bearings were slightly elliptical in some sectors even after the preliminary adjustments described above, indicating that further balancing of the aerial is necessary. In the sector 0 to 90° however all the bearings were good straight lines.

Detailed observations are listed in Appendix 4.

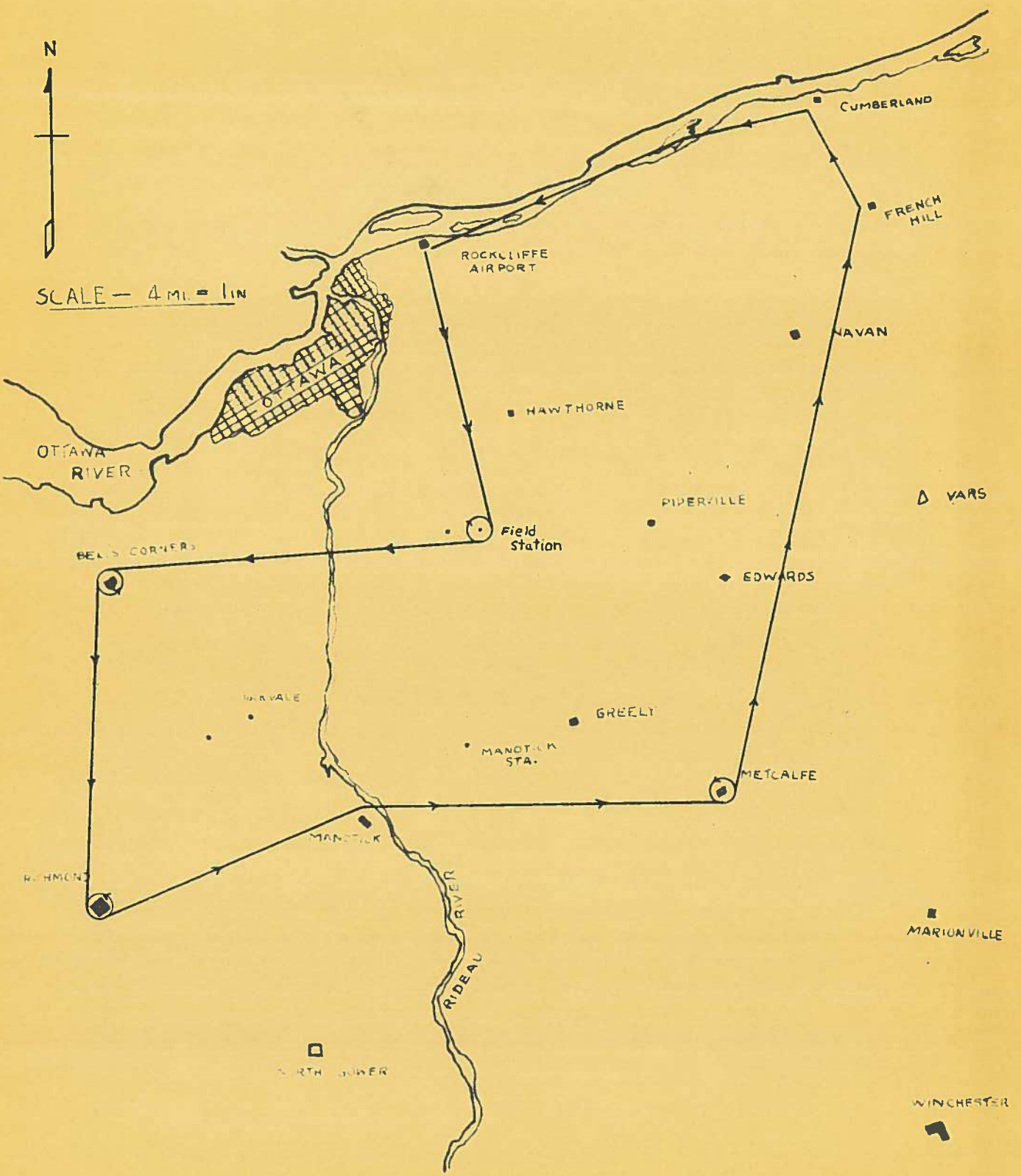
Conclusions

That the combination of a cathode ray direction finder and an Adcock aerial make a very effective instrument for taking bearings on moving aircraft.

That further work on our aerial is necessary to give straight line indication in all quadrants.

NOTE: Two observers from the RCCS were present at these trials viz. Mr. Symons and Mr. Cumming.

FOURTH TEST FLIGHT



FIFTH TEST FLIGHT

Date of Flight

Friday, 4th November, 1938.

Object

To repeat the observations of Thursday, 3rd November, 1938.

Apparatus

The same as for Flight 4, 3rd November.

Procedure

The plane took off at 1415 and started transmitting. Its course was from Rockcliffe to the field station, one two mile circle around the field; west to Bell's Corners; one circle at Bell's Corners, south to Richmond; one circle at Richmond, north-east to field station; south to Manotick, one circle at Manotick; east to Metcalfe, one circle at Metcalfe; north to Navan, one circle; south-west to field, one circle and back to Rockcliffe.

Observations

Mr. A.N.Fraser and Mr. J.W.Baine of the Department of Transport and S/L R.E.McBurney and F/L H. Goodwin of the R.C.A.F.were present to observe this trial and to note the present state of development of the apparatus.

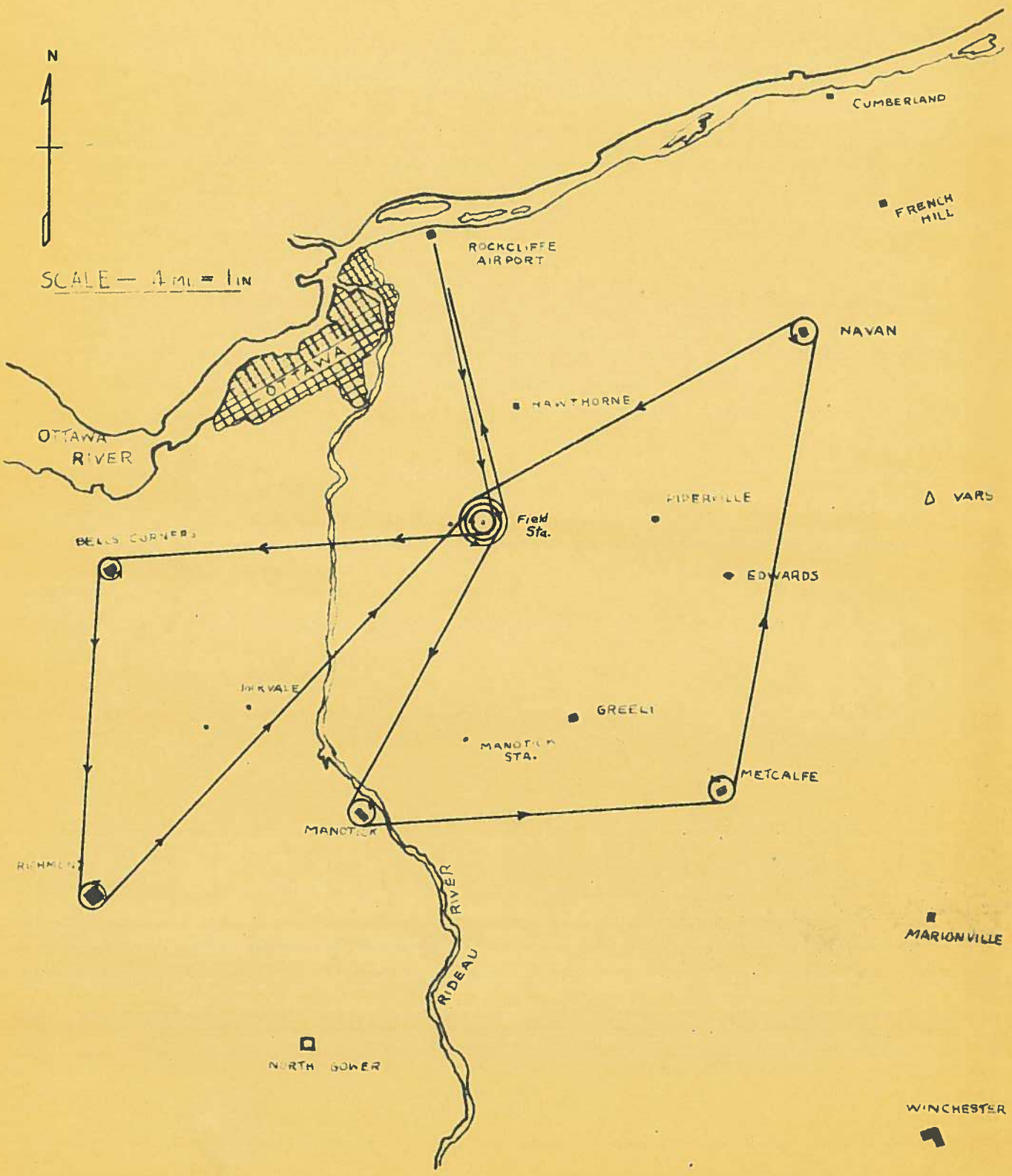
The observations were in line with those of Flight No.4, i.e., the bearings obtained are independent of the orientation of the long trailing antenna used on the plane.

Detailed observations are listed in Appendix 5.

Conclusions

The conclusions of Flight 4 were confirmed.

FIFTH TEST FLIGHT



APPENDIX I

Time	Air Obs.	Position of Plane	True Bearing	Ground Observations
1321-44	Using 75' aerial trial trans-mission		354½°	
1353 1357	Trans-mitter started	Take Off		
1400	VE9HV	Approach-ing D.F. site. Alt.1000'		350°obs'd-Bearing fairly good - Note Added - Probably not far wrong as exact location of field from air uncertain at first and was approached from westward slightly.
1404-07	Numeral I	Climbing Turns over D.F.Station to 3500'		Line goes in circles app-arently 45° in error.
1408	VE9HV	Going Westerly.		90° (or 270°)
1409-13	Numeral 2	Climbing turns over Hunt Club to alt.6000'	264°x	Line moves 45°, pauses, moves 45° other way. Then line moves 60° with 1" loops.
1415-19	Letter V's.	Circles over road & CNR track Location No.3-Alt. 5900'.	267°	Line moves all round tube with loops. Then line going all round tube with no loops but quick reversal when signals small.
1420 - 1422	-			Line holds at 315°for several minutes. Line turns to 300° and loop appears.

Time	Air Obs.	Position of Plane	True Bearing	Ground Observations
1423-27	Letter X	Circles over Jock and Rideau Rivers, Location No.4.	214½°	270°- large ellipse, line turns from 270° to 180° to 270° to 180° to 270° to 180° to 270° to 225°. Assorted loops of 1" minor axis
1429	-	Flying to Manotick		Steady bearing 210° moving slowly to 180°.
1430-33	Letter Y	Circles over Manotick Sta.Location No.5.	178°	Line moves thru ± 90° does quick turn and loop when sig. small. Not such large loops.
1433-35		Flying to Greely		205° steady slowly changing to 180°
1435-39	Letter C	Circles over Greely Location No.6	150°	Line moves back to 190° then to 135° then to 195° to 100° to 195° to 105° finally to 180° with 1" loop.
	VE9HV then steady	Flying to Piperville		170° to 180° to 170° to 150° with loops, to 160° to 150°.
1443-47	Letter R	Circles over Piperville Location No.7.	88°	Line goes from 140° to 45° to 150° to 40° to 150° (without many loops or apparent decreases in signal strength) to 40° to 105°.
1448	VE9HV			Bearing 110° changing to 120°. Signal increasing and changing to 90° to 120°.

Time	Air obs.	Position of Plane	True Bearing	Ground Observations
1451-55	Numeral 8	Circles over Hawthorne Location No.8 Alt. 6000'	25½°	Swinging from 120° all round tube with fadeouts and rapid swinging of small signals-about 1" loop for full scale deflection. Apparently two revolutions on cathode ray tube for one turn of plane.
1455½	Finish Sign			Apparently shuts off.

Note: X True Bearings to Approximate Centre of Turn.

APPENDIX II

E.D.T.	Position of Plane	True Bearing	Ground Observations
1448 1449	Take off	354½°	3° Elliptical. This bearing is 1¼ miles east of airport and plane may have been at this point when climbing.
			Very rapid increase in signal strength of transmitter. (32 DB. in 1½ minutes)
1450			Bearing, ellipse at 315° (or 135°)
1452	Proceeding to G.	264½°	Bearing varies from 315° to 0° to 45°, being about + 45° when at point G.
1455	Circles over G	264½°	About 250° bearing turning into circular pattern on C.R. tube turning to 260° and still elliptical.
1459			Variation of elliptical bearing when plane circles is about ±3° which is about right for plane turning ½ mile circle-bearing changes from ellipse to straight line appears only twice per revolution.
1500	Now proceeding to J	264° to 222°	At about 250° bearing seems approximately correct but bearing elliptical - trailing aerial now broadside on.
1507	Circles over J	221½°	When plane travelling G-J bearing gradually changed thru 235°; 210° to finally 195°. When circling bearing changes about ± 2½°, giving ellipses and straight lines. Note: bearing 195° badly off.
1509	Proceeding to Bellini aerial on Boyds' Farm	221° to 197°	Bearing at first 193° and 194° good readings but wrong direction. Then an ellipse appears and minor axis gradually increases. Bearing then backs up to 205° to 217° to 212° to 215° (large ellipse).

E.D.T.	Position of Plane	True Bearing	Ground Observations
1520			Gain had to be decreased 60 DB. Plane sighted - large signal- ellipse, swinging, no steady bearing.
1522	Circles overhead		Bearing apparently 45° in error, follows plane as it circles overhead. Ellipse at all times.
1526	Proceeding to R	178°	Bearing 135° to 160°
1531	Circles over R	178°	Line swinging 180° ± 22½°, giving straight line due south. This apparently is the first good bearing.
1533	Proceeded to M and circles over M.	148°	Bearing apparently 45° in error when going from R to M. Circles over M give changes of 80° in bearing on Cathode Ray Tube.
1540	Proceeding M to Q	148° to 152°	Good straight line bearings obtained varying from 150° to 155°. Fairly good.
1542			Plane now closer to D.F.station and bearings become elliptical.
1548	Circles over G	152°	4 revolutions of line on C.R.tube for two circles of plane - large ellipses, swinging. When bearing becomes 149° shows as straight line. This possibly is the position when aerial lies in plane of propagation.
1550	Proceeding G to W	152° to 87°	Elliptical bearing going from 160° to 145°.

E.D.T.	Position of Plane	True Bearing	Ground Observations
1551	Circles at W		Bearing goes from 97° to 105°
1554	Coming to Bellini Mast	87°	Bearing 93°, elliptical going to 101° 102° straight line.
1556			Then swinging 110° to 120° and from 170° to 165° as distance decreases.
1558			135° - Plane overhead - shows as straight line.
1559	Going to Airport		Good Bearing 355°.
1600			Ellipse and signal fading rapidly. Swinging line on C.R.tube.
1601			Good bearing - signal increased-358°
1603	Finish Sign.		

APPENDIX III.

Time	Position Obs. from Plane.	True Bearing.	Ground Observations	Remarks.
1515			First signals Elliptical 348°	Airport is
1516	Passed West of Adcock		Large signal 345°-343°-340°	approx.350°
1517	and returned		330°	
1519	from southerly direction		Elliptical rotating counter-clockwise 15°	
1520			Transmitter freq.drifting.	
1523	Circled Adcock		Plane overhead (+5DB)	See note #1
1524	then flying towards Bell's Corners		265° 3/8" E 8"signal volume decreasing, same bearing 1/4" E.	See note #2
1525			266° 1/4" E (-3DB)	
1526			266° (-9DB)	
			266° 1/8" E (-10DB)	
			266° 1/4" E (-12DB)	
			No ellipse	
1527			267° 1/4" E	
			268° No E (-11DB)	
1528½			268½ 1/8" E (-13DB)	vol.varying
			269° 1/4" E (-14DB)	
1529			270° 1/4" E (-16DB)	
1530	Bell's Corners circle	264°	270° No E (-20DB)	
			271° No E	
1531	Proceeding		270°269-267-266-265 No E	
1532	towards		263-262 No E	
1532½	Richmond		260° No E	
1533			257° 3/8" E	
1534			255° 1/4" E (-20DB)	
1533¾			253° 3/8" E Same volume	
1534			251° 3/8" E	
			247° 1/2" E " " (-20DB)	
1534½			244° 1/2" E	
1535			243° 1/2" E Sig.varying	
1536¼			241°	
1537			243°	
1537½	Circle at		243°	
1538	Richmond	227°	243°	

Time	Position obs. from Plane.	True Bearing.	Ground Observations.	Remarks
1539			244½° 1/2" E 245½° 1/2" E Sig.Increasing	
1540	Fallowfield Sta. due N.One Mile.	231°	247° 3/4" E Took down aerial for 20 w. transmitter.	
1541			247½° 1/2" E	
1542			249° 1/2" E	
1542½	Jockvale Village is SW one mile	235°	249½° 1/2" E Turned to 250½	
1543½			253° 1/2" E	
1544	Over South edge Uplands Airport	252°	256° 3/8" E	
1545			258° 1/4" E	
1545+			260° 3/8" E--261° 1/4" E	
1545½			262°;--264° 1/4"E; 267°;-270° -275°; 300° and 2" E	
1546½			Plane Overhead - circle	
1547½	Bound Winchester Hazy at 1500';		100° St.line	See Note #3.
1548	Visibility about two miles		103°, 1/2" E; 107° 3/4"E; 110° 1/2"E.	
1549			113° 1" E	
1550			Changed condenser 113° 1"E becomes 130° 3/4" E	
1551			131° 3/4" E signal weaker	
1552	Metcalfe due West		132° 3/4" E	
1552+	about 1 1/2 mile	133°	133° 1/2" E	
1553			135° 1/2" E--136° 1/2"E	
1554			136° 1/2" E	
1555½	Over Marionville off course to Winchester.	132°	139° 3/4" E	
1557	Approaching		137° 1/2" E--138° 3/4" E	
1558	Chesterville from NW			
1559	Circle over Chesterville	132°	136° to 134° and back to 136° Slight ellipse	
1600			Plane circle ends.135°	
1601	Bound Vars,flying about N30° W.		134°	
1602			134° Signal increasing	
1602½			133° Plane bound Vars	
1603½			132° 3/4" E	
1604			131° 3/4" E	
1605	Over Morewood	124°	127° 3/4" E	
1607			125° 3/4" E	
1608			123° 3/4" E	
1610	Russell due West about 1/2 mile	116°	118° 3/4" E to 116° to 115° 3/4"E; 112°	

Time	Position Obs. from Plane.	True Bearing.	Ground Observations.	Remarks
1611			112° 109° 3/4"E,to 105°	
1612			100°E smaller	
1612+			96°	
1613			95° No E; to 94°; to 91° no E.	
1613½	Now at Vars circle begins		90° No E.	
			87° No E.	
1614			85° " "	
			84° Very small E	
			86° No E.	
			88°	
1615			87°	
			86°	
			85°	
			84°	
1615¼			83°	
			84°	
			85° maybe very small E here.	
			86°	
			87°	
1616			85°	
1616¼	Two circles completes	87°.	85°	
1617	Bound for Adcock		86° to 88°	
1617½			90°; 90° varying ± 1/2°	
1619			90° ± 1/2"(3/8"E appeared momentarily)	
1620	Drifting south		91° ± 1/2	
1620½	passed between	92°	92° 1/4" E	
1621	Edwards and Piperville		93° 3/8"E;to 94° to 95° to 96°, 97°	
1621½			98° 1/2"E; 99°; 100°;	
1622			102°	
			Changed Receivers using MDF4	
1623	Crossed Metcalfe		110° to 115° poor balance	
1623½	Highway 1 mile south	150°	118°, 120°, 122°,	
1624	of Leitrim and headed north.		130°, 135° poor balance, plane roughly 1/2 mile away.Off course.	
1625-27	Circled Adcock then going Piperville		150° Min.Very broad 180° No minimum.	
1630	Circle over Piperville	87°	70° Very broad,minimum. 78°	
1632			70° " " "	
1631			73° to 78°	
1631½			79° good minimum balance far left as possible	
1632	Circle completed		73°; 65° good minimum.	

Time	Position Obs. from Plane.	True Bearing	Ground Observations	Remarks.
	Returning to Airport		48°	
			45° very good, balance hard right.	
			42°	
1633			40°, 38°, 36° weak signal	
			34°, 32°, 27°	
1634			25°, signal quit, no balance should be farther right.	

Note 1.- +5D.B., -9DB etc. are estimates of relative signal strengths.

Note 2.- 3/8"E, 1/4E etc. are values of minor axis of ellipse based on an 8" major axis.

Note 3.- True bearings are probably not more accurate than ± 3° as it is difficult to exactly correlate the observations made on the ground with those made in the plane especially when the plane is drifting with wind.

APPENDIX 4.

EST. Time	Air obs.	Ground obs.	Remarks
1415	Started sending	Placed ground signal for plane to start 2 mile	
1421		circles. Large ellipse from	
1424		Transmitter * 3/4" E, plane now in sight. Indication good until a few hundred feet away from Adcock aerial.	The period from 1426 to 1515 was spent in adjusting the aerials as the plane flew around the field in 2 mile circles
1426	Two mile circles started.	Flying counterclockwise.	
142.		Shorted E.W.aerial.3/4" sig. (N.S.) when plane due W.	
1428		Shorted N.S.aerial,3/8"sig. (EW) when plane due S.	
1432		Shorted E.W.aerial.1" sig. (NS) when plane due E.	
1434		Shorted N.S.aerial 3/8" sig. (EW) when plane due N.	
1435		Adjusted condenser on S aerial when plane due W. (EW aerial shorted).Signal went thru zero (i.e.condenser turned too far.	
1440		Ellipse when signal at 225°	
1442		N.S.shorted; plane due S still gives residual signal in E.W. aerial -Bearings straight lines in sector 140° to 125°.-Then elliptical as far as 90°.-When plane E and EW aerial shorted-1/4" E. on NS.	
1443		At 60 line straight.(remains	
1445		so until 355°). Shorted NS.	
1446		Plane N.EW=zero.From 330°,300°	
1447		bad ellipse, shorted EW aerial	
1451		Plane W.NS=zero.Adjusted coupling coils in receiver commoning device works better.	
1451+		From 30° to 10° bearing st. line.	
1452		Shorted NS,Plane N.EW sig. goes to small line at 45°, becoming dot when plane due N.	

* - All minor axes of ellipses referred to major axis of 8".

EST. Time	Air obs.	Ground obs.	Remarks
1453		340° Ell.320° Bad ell.	
1454		E.W.shorted, Plane W.NS=1/4"	
1455		260°, good st.line bearing.	
1456		24 °, and on, elliptical	
1457		NS shorted, plane S,EW=3/4"	
		Plane then came to centre	
1500		EW shorted.Plane W,adjusted	
		NS aerial for zero signal	
1502		210° Bad ellipse.	
1503		NS shorted,Plane S.EW	
		does not go to zero,about 1/2".	
1504		EW shorted,Plane E, NS=3/8"	
1507		NS shorted,Plane N. EW=zero	
1508		310° ellipse.	
1509		EW shorted, Plane W.NS=zero	
1511		when plane SE,bearing st.line.	
1512		EW shorted,Plane E,adjusted	
		NS and removed 1/2" signal	
		From east to north directions	
		fairly good.	
1514		Plane north, 1/8" E	
1515		Changed ground signal for plane	
		to start to Bell's Corners.	

		True Bearing.	
1518	Over Adcock		Bearing fairly good until
	bound Bell's		plane very close.
1522	Corners		265½°
1525			266°
1526	Bell's Corners		No change in straight line
	one circle	264°	when plane circle
1528			Interference from station send-
			ing "OM"
1533			237° 3/8" E.
1534	Richmond	227°	231° Keying
	one circle		No change in ellipse and
			only small variation in
			bearing.
1538	Bound for		Bearing changing but still
	Metcalfe		elliptical.
1541	Manotick	202°	198°
	SW ½ mile		
1543			Due south 3/4"E
1544			164°, 3/4"E
1546	Circling	138°	Bearing varies 136° to 138½°
	Metcalfe		no change in shape of ellipse 1/2"E.

EST Time	Air obs.	True Bearing	Ground obs.		Remarks
1548	Bound Navan, missed it in smoke haze, passed over French Hill arrived at Cumberland.	39°	122° Due East 50°	straight line straight line	Note 1.
1600 1601	Over O'Connor's Island.	28°	29°	straight line	
1605	Over Duck Island		15°	straight line.	
	Signed off.	6°			

NOTE: 1. It is hard to correlate the observations of position from the air and on the ground from 1548 to 1605.

APPENDIX 5.

Time	Position obs. from plane.	True Bearing	Ground obs.	Remarks
1415	Up and on the air.		First signals.	
1420	In sight of field			
1423	Begin circles		Tuned antennae	
1435	Bound Bell's Corners.		Starts 287°-280°-270° elliptical ellipse disappears as plane moves away.	
1443	Start circle at Bell's Corners	264°	Not much change of bearing.	Note 1.
1445	End circle bound Richmond		as plane circled. Bearing elliptical from 240° on.	
1453	Circle at Richmond.	227°	No change as plane circles.	
1455	Bound Adcock			
1507			Plane sighted moving west of 215° agreeing with bearing.	
1502	Circle over field			
1504	Bound Manotick			
1510½	Circle Manotick	204°	204°	
1511½	Bound Metcalfe			
1517	Circle Metcalfe	138°	146° elliptical	
1519	Bound Navan			
1523	Transmitter trouble		Transmitter trouble.	
1527	Circle Navan			
1529	Bound Adcock		Observations discontinued	
1536	Over field			
1538	Bound Airport			
1544	Landing		Signal off.	

NOTE: 1. This flight was primarily a demonstration and observations of bearings on the ground were not continuous.