Work in WW2 on Radio Propagation Forecasting for Communications

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(Prepared by R W Madsen, October 20, 2018)

Introduction.

In 1930 JPVM (Professor John Percival Vissing Madsen) at the University of Sydney introduced a course of lectures in Electrical Communications which could be taken by students with the necessary scientific training & also subject to the Faculty of Engineering approval. This course could be taken as an alternative to Electrical Engineering II in the fourth year of a candidate working to a Bachelor of Engineering (Electrical). Students had the opportunity of becoming involved with the research activities of the RRB (Radio Research Board) Sydney Group organised by JPVM & which had progressed extremely well by 1934 as indicated by a letter to the University Senate from the Director General of the PMG (Post Master General's Dept.-Mr H B Brown) which referred to the fact that the radio research work carried out in the Department of Electrical Engineering had produced results of striking national importance. The work on the Ionosphere which JPVM was most closely involved (as opposed to Atmospheric work led by Prof. T. Laby at Melbourne University) he summarised in 1935 in the John Murtagh Macrossan Lecture for the University of Queensland. Ernest Rutherford at an International Conference in Vancouver at this time also complimented the valuable work being done by the RRB.

At the outbreak of the war most RRB personnel moved into radar work with the RPL (Radiophysics Laboratory in the University of Sydney grounds), however Dr. F W Wood remained in JPVM's Dept. & working almost entirely by himself began to develop methods of data analysis of the Ionosphere & prediction of frequencies for use by the fighting services. The assistance of Dr. F W G White from 1941 was of immense help in pushing through support for Wood to build up the Ionospheric Prediction Service for Australia.

In April 1944 an international conference was held in Washington DC & in fact solved a lot of problems including the "longitude effect". Besides Wood, Australia was also represented by S/L A L Hall of the RAAF who made particular mention of "skip" problems which he indicated had been overcome by the selection of frequencies based on the use of ionospheric data. An International Conference had also been held in the UK on March 20, 1944.

There is current interest from the US on the success of the Communication operations in Macarthur's SWPA in WW2 on concerns that communication satellites could be destroyed by Russia/China missiles.

1975 Paper to the Royal Society on Early Radio Work up to 1945.by Sir Frederick White.

The following notes from Fred White's paper ("Early work in Australia, New Zealand and at the Halley Stewart Laboratory, London" Phil. Trans R.Soc Lond 280 (1975) relate to F W Wood's Ionospheric work.

The outbreak of the war in 1939 brought the diversion of many of the ionospheric researchers at the RRB to radar, at the RPL. The possibility of ionospheric data being used to forecast the propagation conditions for communications by radio was known but not widely appreciated at this time. The US National Bureau of Standards was already, in May 1937, publishing weekly forecasts of radio transmission conditions.

F W Wood, who had been with Appleton at the Halley Stewart Laboratory, returned to Australia in 1937 to join the Sydney RRB group. Originally from Western Australia & with experience first at Watheroo & later at the Royal Aircraft Establishment at Farnborough, Frank Wood was to develop a unique understanding of the analysis of ionospheric data for use by fighting services.

Watheroo is located north of Perth in Western Australia, some 80 km inland from the sea in a sandy waste with characteristic desert vegetation. It was here that the Carnegie Institution of Washington established its Magnetic Observatory-one of a chain of such stations designed to provide information on the Earth's magnetism & electricity. When the Department of Terrestrial Magnetism of that Institution became interested in the ionosphere, this Western Australian observatory, with Washington & Huancayo, was made one of their three major ionospheric observatories. Dr . L V Berkner designed for these stations automatic ionosonde equipment & in 1938 he installed this equipment at Watheroo & spent six months visiting in Sydney & Melbourne with the RRB scientific teams.

Left almost alone in Madsen's Dept at Sydney University, but later joined by L S Prior, also from Watheroo, Wood began to develop methods of data analysis & prediction. Primary data were, at the outbreak of war, available only from Sydney, Mount Stromlo, Watheroo & Christchurch. Stimulated by service interest, money became available to permit the building of additional recorders for Brisbane, Cape York, Charters Towers, Hobart & Admiralty Island. New Zealand put stations in Fiji, Campbell Island & the Kermadec Islands. About 1943 new instruments were made to performance requirements specified by the Board (RRB) & their construction was supervised by A J Higgs.

Under the auspices of the Australian Radio Propagation Committee, the Sydney Laboratory became one of three Allied centres for the collection & analysis of data from these stations & from the many others established by Great Britain , Canada & the USA. Frank Wood initiated this effort in Australia & was responsible throughout the war for its scientific development & management.

The great increase in the number of automatic ionospheric recorders due to the efforts of those countries interested in wartime prediction provided much information on the temporal and geographic variations in upper atmosphere ionisation. For the first time the "longitude effect" became noticed as well as the daily & seasonal anomalies of the F-region. The effect of magnetic storms & solar eruptions causing radio fade outs could be more easily interpreted.

<u>Notes on Ionisation Prediction Services in WW2 by Prof. R W Home (& S G Kohlstedt)</u>

[Professor R W Home, science historian from Melbourne University, prepared the Historical Record of the Bragg, Rutherford Madsen letters for the Australian Academy of Science.]

F W Wood worked with the vastly undermanned RRB at Sydney University in JPVM's Electrical Engineering Dept, to develop ionospheric predictions for the Australian services, particularly the military & the Government's civilian short wave service.

By 1940-41 Wood was receiving ionospheric data from Madras (India), NZ, Washington DC, Huancayo (Peru) & England. He would later receive data from US Stations at Cambridge Massachusetts, Stanford California, Baton Rouge Louisiana & Puerto Rico. His network in Australia consisted of sounders at Watheroo, the Mount Stromlo Observatory & Sydney & he had several years of Australian data.

White (originally from Christchurch & came to RPL in April 1941) & Wood had both worked with Appleton in England & White was of immense help in pushing through support for Wood to build up the Ionospheric Prediction Service for Australia.

The radio prediction system to be effective (& with Australia playing a central role) necessitated a complicated international operation that called for more & more co-operation as the war progressed. (In 1941 F W G White, E V Appleton & J H Dellinger, Director of the US NBS Radio Laboratories, simultaneously suggested the need for better Allied co-operation in radio forecasting). A major radio propagation conference for the Allies was held in Washington in the Spring of 1944 to deal with problems eg. In the New Guinea jungles radio equipment suffered a heavy toll despite Australian tropic proofing knowledge & radio operations were nearly impossible- signals did not get through. Also, Armies typically needed short range forecasting accuracy, whereas Navies needed forecasting in areas, such as vast ocean surfaces, for which there was little applicable data. The beam broadcasting services between North America & the British Empire needed very long distance forecasts.

Four Networks were used by the Allies:

The Americans established a combined military-civilian propagation laboratory at the Bureau of Standards in Washington (IRPL-the Interservice Radio Propagation Laboratory, using Newbern Smith's transmission curve method of forecasting)

The British had two somewhat antagonistic groups: 1) T L Eckersley (ISIB-Interservice Ionospheric Bureau operating for the British Military & co-operated closely with the Americans using a forecast model approximate to that of Newbern Smith). 2)E Appleton (Radio Research Station Slough working for the British civil radio using the Appleton-Beynan periodic layer model- Appleton & Eckersley had not personally got along since 1930).

The Australian services originally used Smith's curves, then changed to a version of their own, using Appleton's model (It was claimed that there were differences of 20% to 50% in the values of the predicted optimum working frequencies depending on the forecast model chosen.

A good part of the problem was due to the asymmetry & displacement of the Earth's geographic co-ordinates & the geomagnetic field. Basically, the Earth's ionised layers are partly controlled by solar radiation & its interaction with gases in the upper atmosphere. Thus, geographic latitude & longitude play a role, but the geomagnetic field also plays a part in ionospheric currents & density distribution. The geomagnetic field is skewed so that some equatorial latitudes are more like some mid-latitudes, in other words there is a "longitude effect" to the ionisation of the upper F2 region of the ionosphere. Failure to recognise & allow for this leads to significant errors (30% to 100%) in propagation forecasting. (In April 1944 at the International Radio Propagation Conference in Washington the "longitude effect" was discussed by all. The discovery of the "longitude effect" was first discovered in Japan (K.Maeda, H. Uyeda & H.Shinkawa) & published in Japanese in April 1942 (Published in English as an abstract for the first time in May 1962 by IEEE/IRE) & subsequently by others in the west in 1943. In December 1941, FWG White & F Wood discussed with the Military the fact that data from Huancayo, Peru, was not good for Port Moresby, although they may not at the time have understood the reason why).

The Washington Conference solved a lot of problems:-

. the solution to successful jungle radio transmissions was to get the antennas above the jungle cover & utilize sky waves rather than ground waves.

.the “longitude effect” would be studied by utilising new stations put into operation in 1944 & by utilising the corrected tables issued by Groups such as IRPL.

.Atmospheric noise was a great problem in the Australian area of operation in the SWPA & would be studied further.

.Supposedly slight changes made to the applications of the various models reduced the difference in forecasts to a mere 2 to 3%.

.The British to co-ordinate their two competing Groups, as the ISIB, US –IRL & Australian Groups had been doing since 1942.

Australia was represented at these meetings by Dr George Munro, the Aust. scientific Representative in Washington, F W Wood representing the RRB, by S/L A L Hall of the RAAF & by Lt. A W Moriarty of the RAN (NZ also had representatives).

S/L A L Hall talk in London & Washington in March-April 1944.

(CIC Combat Information Center Magazine August 1944) Synopsis.

“Farewell to Communication Failures”.

It seems to be rather a common belief that one has only to set up two transmitters & associated receivers, covering some arbitrarily selected frequency range, to guarantee communication between any two points, any time of the day or night, without regard to the nature of the medium through which the waves pass. Otherwise reliable communication officers who neglect the medium, are just hoping for the best. The medium through which the radio waves are to travel can be accurately predicted by the use of ionospheric data, & contact thus ensured between any two points day & night throughout the year. The application of this method in the SWPA from 1940 on provides illustrations of what can be achieved.

Radio networks as reliable as land-lines:

In wartime, delays in the order of 10 minutes or so may make all the difference between the success or failure of an important operation. A survey of Australian communications in 1939 revealed that the system was unsatisfactory, in particular as there was practically no W/T point-to-point circuits, an overloaded trunkline telephone system which was only to the main capital cities & not to northerly areas such as Darwin. Also the W/T with New Guinea was unsatisfactory.

To meet this critical situation, it was decided to establish a comprehensive W/T point-to-point system which would operate 24 hours of the day, 365 days of the year. The network of point-to-point services in Australia has grown from less than 10 circuits in 1939 to well over 500 circuits, all working with clockwork regularity. Co-operation to the fullest degree was given by scientific organisations in supplying wave propagation data based on earlier researches into the characteristics of the ionosphere (RRB , PMG). Subsequent experience has shown that, provided frequency allocations are based on adequate knowledge of the ionosphere, communication is for all practical purposes is as good as that over land lines.

Air to ground contact assured:

It is important that communication between aircraft & base be maintained at all times eg during a reconnaissance flight, so that sighting reports can be made without delay back to base to enable appropriate offensive action to be taken against the enemy.

Prior to the application of ionospheric predictions in the SWPA failures were frequent, in particular near the dawn period, but also quite often at other times of the day. It had been customary to employ frequencies in the region of 6 Mcs on which channels partial success had been achieved.[Coastwatchers transmitted by Teleradios on a single frequency in the 6 Mcs band to Coastal Radio Service stations which had dedicated receivers constantly tune to this frequency, the “X” frequency, 24 hours per day & on loudspeaker] At dawn, however, these frequencies were much too high, having skips of the order of a thousand miles or more, and at mid-day having short distance ranges, due to high absorption. The selection of frequencies based on ionospheric predictions completely eliminated practically all difficulties in communicating with aircraft.

On strike missions & also aircraft sent to protect convoys, distances to a target may be as much as a thousand miles so that schedules of frequencies & times of operation on each have to be carefully worked out in advance so that continuous communication may be ensured.

Ship to shore failures have been costly:

The need for a Navy commander to call for fighter cover & also to receive warnings of likely submarine attack requires frequencies to be carefully planned using ionospheric data to assist, so that areas are not skipped.

Meteorology eliminates failures:

In the Australian theatre there exists a network of widely separated key meteorological stations which interchange information by a W/T network with each other & then must inform all airfields within its area of the synoptic charts. The frequencies used & their time of operation are all planned on the basis of ionospheric predictions & no failures now arise (at first equipment in use could not reach sufficiently low frequencies, but later equipment was installed eliminating the difficulty).

Direction finding saves planes:

In the SWPA high frequency direction finding is used as a navigational aid to aircraft & no heavy losses have been experienced due to the selection of the wrong frequency, resulting in an aircraft being in the skip zone. The SWPA has been divided into zones, time tables carefully drawn up & selected frequencies laid down for each zone, thus ensuring that no aircraft shall be within skip of the D/F station at any time, day or night. No failures have arisen except where instructions have been disobeyed, & frequencies used involving skip (eg. A Hudson flight with 10 people aboard on a flight from Horn Island to Brisbane in bad weather where the ground station would not accept the advice to go to a lower frequency because of a fear of loss of communication with the plane which crashed) .

Operational Channels scientifically planned:

Just prior to the Coral Sea Battle, a meeting was hastily called at General Macarthur’s HQ to decide ways & means of ensuring communications between ground stations, ships, aircraft & organisations vitally concerned with obtaining information which would enable them to follow the course of the anticipated battle & take appropriate action. Because of the number & disposition of the forces concerned, both in the South & SWPA, the system of necessity had to be as simple as possible. Some communication officers at the conference therefore advocated the use of a single frequency. It was pointed out by reference to ionospheric predictions, that if this plan was adopted, communication failures would inevitably result. The more scientific approach was finally agreed upon, & additional frequencies were selected, the hours of operation on each being specified in advance. The plan was completely successful & as far as is known there was not a single hitch during the battle due to a communication failure.

Since the time of the Coral Sea Battle, reconnaissance, strike, convoy & broadcast frequency allocations in SWPA have been based on ionospheric data & the success has amply justified the comparatively small expenditure of effort in this direction.

[The Battle of Savo Island on August 8, 1942 was carried out as a complete surprise by 5 Japanese heavy cruisers with “long lance” torpedoes from Rabaul & resulted in the sinking of 4 Allied heavy cruisers, including HMAS Canberra. Lack of proper communications by the Americans & Australian services was a crucial factor in this severe loss. Eg. No TBS –Talk Between Ships].

Locating source of signals:

Ionospheric information has proved of considerable value to Signals Intelligence Units in identifying where skip distances were involved when the source of strong signals were in fact in excess of 1,000 miles distant. Ionospheric forecasts, coupled with regular monthly predictions are now in general use so that cause & effect of eg. An ionospheric storm suggesting a sudden increase in traffic can be more readily determined.

<u>Role of Science & Industry WW2: Communications</u>

<u>(Australian War Memorial History- D P Mellor, 1958.).</u>

A comprehensive account of radio communications is included in the Communications chapter of this history at pages 502-509 including the role of JPVM & also discussion of the “longitude effect”.

Notes:

An important contribution to the application of ionospheric data to the prediction of communication frequencies had been made by D F Martyn at the RRB, with the discovery that there was a simple relation between the critical frequency at vertical incidence, & the maximum frequency that could be used at oblique incidence without penetrating the ionosphere. However changes in the F2 region of the ionosphere proved to be more complex.

The need for Allied co-ordination became apparent when attempts at prediction for the SWPA by the British Service (based in London), the American Service (based in Washington) & the Australian Service (based in Sydney) frequently differed. A particular difficulty arose in New Guinea where the Australian Service had assumed that the data gathered at Huancayo (Peru) would apply to Port Moresby which are at about the same latitude ; it was found however that signals were not getting through on the frequencies predicted. A clue to the inconsistencies of the prediction for New Guinea was revealed at the Bureau of Standards who noticed that ionospheric conditions at stations in America just north of the equator were very similar to those at stations just south of the equator, on the other side of the Earth.

This asymmetry of the ionosphere about the geographic equator was traced to the fact that the geomagnetic equator was a controlling factor. In the neighbourhood of Port Moresby the geomagnetic equator was about 12 degrees North latitude, while Huancayo was about 12 degrees south latitude.

The Japanese had earlier become aware of the significance of the geomagnetic equator & had set up a string of observing stations along it. From a scientific viewpoint the Japanese data was reliable, but they were presented in a form for use only by experts; however Japanese scientists were not able to convince their Services of the usefulness of ionospheric predictions & the value of these excellent observations was largely lost.

Allowing for sunspot activity (which follows a very regular cycle) predictions of considerable accuracy of ionospheric conditions could be made which usually took the form of graphs showing the maximum useable frequency for distances up to 2,000 miles ie. for transmissions involving principally one reflection from the ionosphere. Such graphs were prepared for each 10 degrees of latitude & showed the average values for that month for each hour of the day, issued 3 months in advance.

The Navy preferred tables that the layman could follow, but in nautical miles.

The Air Force preferred curves & contours because they gave a more complete information, especially for mobile units.

The Army preferred curves for a particular latitude, since a whole force could work on the same curve for long periods.

Looking at current Japanese space weather research activities (M . Ishii 2016) he noted that Japan is located at a low geomagnetic latitude & the social impact of severe space weather is mainly on radio propagation, which effects the utility of HF, VHF & Global Navigation Satellite System., & accordingly the amount of space weather research in this area is very high. He also notes that research for stable radio communications started before WW2.

Solar Cycle 17