the
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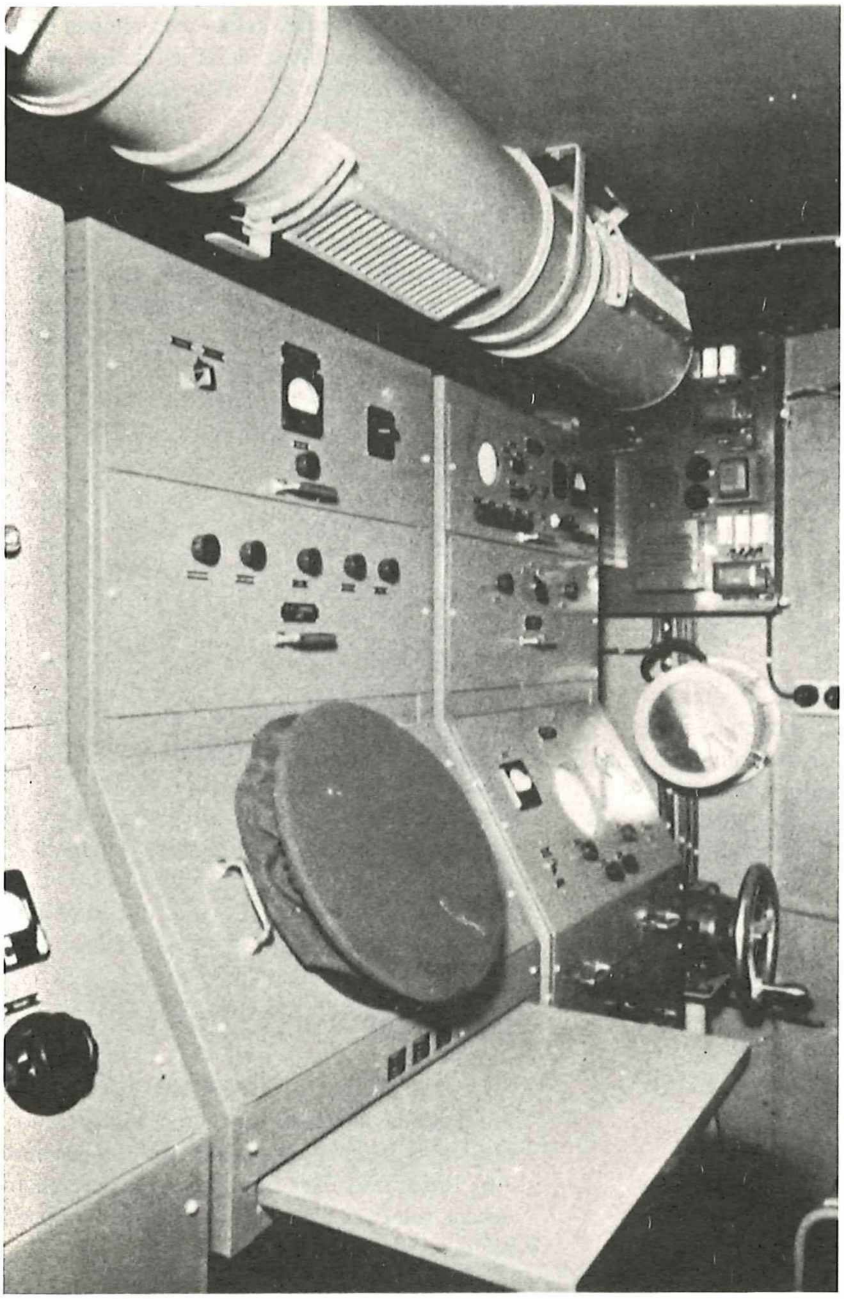

The Radioscientist

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NOTICE TO CONTRIBUTORS

All material should be sent direct to the Editor, preferably by email or on disk as "flat" or pure ASCII text files. The Editor reserves the right to accept, reject, defer and/or edit any material and all material submitted.

COVER: Interior of NZ radar truck used in the Pacific in WW II (see Figure 5 in feature article this issue)

More service, less costs

Two years ago I was given an extra academic staff (faculty) position to fill. I accordingly directed the University administration to place advertisements in all the main journals like *New Scientist, Physics Today*, and *Nature*. This worked well and we got an excellent person. However, the administration warned me that this was the last set of advertisements to be centrally funded. In future all such advertisements are to be funded by the Department requiring the advertisements. What's more, this particular set of advertisements cost nearly one quarter of the appointee's salary.

When I looked into advertising charges made by each journal and magazine I found that single placement costs ranged over an order of magnitude depending on circulation and prestige. Magazines having a small, specialised audience tend to have low charges. If the position you have available fits that magazine's speciality, then every reader looking for a new job is a potential candidate. And an advertisement placement in specialised, low circulation magazines tends to cost you little anyhow.

The Radioscientist is a specialist magazine for radio scientists and engineers. If your university or institute or company is seeking a radio scientist and engineer, particularly if you want applications from all over the world, then place an advertisement in *the Radioscientist.* You would be doing yourself a favour, providing a service to readers and reducing the financial burden to URSI of this magazine (I hope to zero, since there could be objections if magazines received by radio scientists are seen to be subsidised by URSI).

The prices are given inside the cover page on your left as you read this. A half page display ad (long dimension vertical or horizontal) with your institute's or company's logo etc., costs only $130 for one insertion and only half this for additional insertions. Note that small classified ads can be free!

If you live in one of the remote corners of the world like NZ, you will be familiar with job advertisements with deadlines already past when you get your surface mailed copy of that glossy magazine. We get around that. All copies of *the Radioscientist* are delivered by air so that a potential candidate could be reading and responding to your advertisement within two months of you sending your ad to us (but you would be wise to leave an extra month!).

More benefits

The American Geophysical Union (AGU), which publishes the URSI sponsored journal RADIO SCIENCE, will extend the subscription discount now available to AGU members to URSI "members" which will be identified from our list of subscribers to *the Radioscientist* and those URSI officials who receive personally addressed copies of *the Radioscientist.* There is a second echelon of URSI people who receive personally addressed copies of the *Bulletin* but not *the Radioscientist.* These may receive *the Radioscientist* as well, in the same personally addressed package as the *Bulletin* and by air, for only $6 for the next 5 issues (to June, 1993). Such subscriptions should be sent to the Dunedin office in the usual way (email, fax or letter).

The new look

This issue is the first to be printed in Belgium. It is prepared just short of the plate making stage in Dunedin, NZ, using Macintosh computers. The text and graphics is put together using PageMaker 4.01. This application can take text from most of the common word processors, whether for the Macintosh or IBM PC or its clones, including ordinary "flat" text (i. e., ASCII or "text only") which contributors send by email. In fact its "smart ASCII" filter can distinguish paragraph ends (double carriage returns) from line ends (single carriage returns) and convert both appropriately. So emailed text is most welcome. Unfortunately, it cannot handle TeX or LaTeX (nor can anything else, as far as I know). *So please don't email TeX files unless you include an ASCII version as well.* If I get only a TeX file, especially one containing mathematical equations, I have to have it printed out (in TeX, of course) and then have it "retyped" (rekeyed) off the print out in Word 4 with all the maths reconstructed by hand.

Despite a few quirks, PageMaker is a delight to use. At the end of this column I refer you to page 24 for continuation. The text there is linked to this so that if I add text later the excess automatically flows to page 24 (or flows back if I erase some text on this page).

The graphics are done in MacDraw Pro, saved as Encapsulated Post Script Files (EPSF) and imported into PageMaker. This is how I get the graduated grey backgrounds. Typesetting is done from this file on a Varityper PostScript imagesetter which has a resolution of 2400 dots per inch (dpi) and which PageMaker "knows" about (it is included in PageMaker's list of printers).

I prepare *the Radioscientist* in A3 pages of 2 A4 pages just as they are to be printed. Thus the first A3 page forms the cover with the blue banner, with page 28 on its left side and page 1 on its right. The next has page 2 on its left and page 27 on its right, and so on for 14 A3 pages printed ultimately on 7 A3 sheets.

The Varityper printout (on very high quality paper strip) includes the EPSF graphics but not the photographs which have to be screened and placed by hand. Later this year we hope to have a photo scanner to convert photos to digital form for import to PageMaker.

Finally a 1:1 film of the A3 pages is made for sending to Belgium for making the plates and printing the issue. By

(continued on page 24)

SCANNING THE ISSUE

Radar 50 years ago

If one side in World War II had somehow been denied radio for communication, navigation, location and ranging (radar), I suggest that side would have lost regardless. Maybe radar alone would have been enough to have tipped the balance. As we saw in the article by Gentei Sato in the October issue of *the Radioscientist*, it was only at the fall of Singapore, only weeks over 50 years ago as you read this, that the Japanese military rediscovered their Yagi antenna, an important component of VHF and UHF radar. In the USA, microwave radar began with the founding of the Radiation Laboratory of MIT in November, 1940 as described here in ***The Radiation Laboratory — Fifty Years Later***, an abridged version of the article published in the AP-S *Magazine*, October, 1991, and hereby acknowledged. On January 4, 1941, radar echoes were first received at MIT from buildings across the river.

Meanwhile, in sparse New Zealand (population 1.7 million in 1939), the world's most isolated country and with almost no industry not based on agriculture, development on military radar began in 1939. The first radar echoes were received in Wellington by the end of 1939. By mid 1940 NZ radar sets were operating on navy ships and were being developed for coastal defence. By 1942, 50 years ago, over a dozen radar sets were operating over the full length of the NZ coast as well as in the Pacific islands to the north. This fascinating story, ***The Development of Radar in NZ in World War II***, is this issue's main feature. If you picked up a copy of Vol. 1, N° 1 of *the Radioscientist* at the XXIII G.A. of URSI at Prague you may remember the article about radar in South Africa in WW II which was also initiated by Ernest Marsden on his way back to NZ from Britain.

The rapid development of radio science and technology in those crucial times just 50 years ago makes a thrilling story. This is not to glorify war, for the war can be regarded as just the cause of all this progress in radio science. So to celebrate the jubilee of this progress, not the War, can you find an old (70+) colleague who might write us a first hand account? Of particular interest would be German and Japanese radar development at this time.

New sections

There were no ***Letters*** in time in response to either my editorial comments or those of our Guest Editor. So I have introduced ***News and Views*** for short contributions or notes of a "nonpolitical" nature, meaning ones concerning science and people rather than, say, the future of URSI. Some of these were taken from the *VERSIM* newsletter and are acknowledged at the end of each one. More will be taken from other newsletters of URSI Commissions and Working Groups in future if the newsletter editors send me copies.

There are two ***Research Letters***, one by James Wait who pointed out on submitting it that *Radio Science* has no such letters section so that the *Radioscientist* might fill that role. I believe that some articles published in *the Radioscientist* have already been cited. It was for that reason, and on request, that I use page numbering starting from the beginning of each year (volume). So submit your short "learned" articles to *the Radioscientist.* It may not have the prestige of some journals, but you can expect publication in the next or next-but-one issue if your submission is accepted (100% so far!).

We have three ***Book Reviews***, all written by our Review Editor, James Wait. If you have books as an author or publisher to be reviewed, or if you would like to help out and review books, write, fax or phone James Wait. The series of reviews by Alan McCord of software applications which enable **computing without programming**, which ran throughout 1991, have come to an end which will be only temporary if I get some indication that readers want the series to continue.

Wanted!

Interesting and striking photographs for *the Radioscientist* front cover. The subject should be identifiable as radio physics or engineering within the URSI range of Commissions A to K. Until we can afford colour, prints should be glossy black and white and sized to fit on the cover without enlargement/reduction by us. The "portrait" format used so far on our cover is preferred but a striking photograph or graphic (e.g., analogue data) which needs "landscape" mode (short and wide) is also welcome.

Please send submissions together with a descriptive caption to :

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Hertz Medal for James Wait

The 1992 Heinrich Hertz Medal of IEEE has been awarded to James R. Wait

"for fundamental contributions to electromagnetic theory, to the study of propagation of Hertzian waves through the atmosphere, ionosphere and the earth, and to their applications in communications, navigation and geophysical exploration"

On behalf of the URSI community, I offer our heartiest congratulations!

Update on H^{i}Scat

[*See the* "H^{i}Scat" *article in the December issue of* the Radioscientist — Ed.]

Things are happening so fast, especially in our "near zone", and this affects the H^{i}Scat project in several ways. Mostly for the better but the current chaos in Russia may, in the worst case, have a negative impact on the antenna project.

During our visit in USSR/Russia in October and a very exhausting but successful heating campaign at the "Sura" facility, we discussed H^{i}Scat at quite some length with our colleagues there. We agreed that we should not, as initially planned, hurry up with the Feasibility Study and finish it before the end of 1991. Instead we decided to plan a "brain storming" workshop here in Uppsala in the May-June '92 time frame; the exact date and other details have to be worked out when I have a better grip on our finances. The idea is that a limited group of "H^{i}Scat enthusiasts", each with their own speciality, should get together and work hard on the Feasilbility Study Report. We all emphasized that it is extremely important to focus on *unique* possibilities, available *only* at H^{i}Scat and nowhere else, in order to find enough funding.

After the return from Russia, we had two visitors from Moscow: Cyril Zybin from the Lebedev Institute and Nikolay Borisov from IZMIRAN. Both of them are theorists and we had very interesting discussions regarding H^{i}Scat and the possible new physics. Dr. Borisov and I finished a draft on gas breakdown in very strong RF fields to be included in the report. Dr. Borisov left Sweden on Nov 11.

On Nov 22 we had a meeting at our institute with the Royal Swedish Academy of Sciences. The idea was to try to convince the Academy to sponsor H^{i}Scat in one way or another, and to ask for their assistance in establishing contacts around the world. As you know, the Academy is considered an extremely prestigious institution, both nationally and internationally, (the Nobel prize and all that...) and we hope their support will help us getting H^{i}Scat "off the ground".

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VLF fields in Europe

The following note by Neil Thomson appeared in VERSIM. The problem he mentions here was uncovered while on sabbatical at British Antarctic Survey, Cambridge, where he investigated VLF transmitters for use in VLF sounding of the ionosphere and magnetosphere and of anomalies in the lower ionosphere. MSK (Minimum Shift Keying) modulation involves shifting between two frequencies (e. g., 16.0/ 15.95) and phases — Ed.

VLF field strength measurements were made with a calibrated portable loop at a variety of sites around continental Europe and the UK. British transmitters monitored wereGBR (100 baud MSK, 16.0/15.95 kHz), GBZ (100 baud MSK, 19.55/19.6 kHz), and GQD (50 baud FSK, 19.0/19.05 kHz). Also monitored were two powerful transmitters in Western Europe, not well known to VLF experimenters, one in France and the other in (West) Germany. The purpose of the measurements is to help characterize the parameters (β, h) which give the best fits and hence the best modal representation in the NOSC subionospheric computer program.

The French transmitter radiates about 200 kW of 200 baud MSK at a frequency of 18.25/18.35 kHz. It has the nice features of phase-stable carrier and modulation and transmits (what appears to be) random code continuously apart from a few hours off (for maintenance) on Wednesdays. It is thus just like the large US Navy communication transmitters (NAA, NSS, NAU, NLK, NWC, NPM, NDT). This French transmitter is located at 46° 42.5' N, 1° 14.5' E, near the village of Rosnay about 70 km east of Poitiers. Its antenna appears to be currently tuned 20-30Hz above 18.300 kHz and is thus favouring the upper sidebands. This is not a significant disadvantage for most purposes though (the radiated frequency is not affected) and presumably this will be corrected—it is certainly in their interests to do so!

The German transmitter seems to be radiating about 300 kW at 23.4 kHz with some form of non-phase-stable 50 baud FSK. It is located at 53° 5' N, 7° 37' E near the town of Ramsloh (about 80 km west of Bremen. It is most unfortunate that this transmitter is radiating on exactly the same frequency as the US Navy's 600 kW, 200 baud MSK, phase-stable transmitter on Hawaii. Admittedly NPM cannot be received in Northern Europe, probably because the path goes over highly-attenuating Greenland, but all of these VLF transmitters inevitably have world wide penetration. Over a large part of the Earth's surface each must be rendering the other unusable. Even in New Zealand, where NPM is very much stronger, we find that whistler-mode signals from NPM are destroyed when the German transmitter is radiating from half a world away. If anyone knows how to get the owners (military/Government in both cases) to talk to each other, we should all be better off!

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Manmade effects

The consequences of anthropogenic influences on nature are well known. These problems are broadly discussed both by scientists and the mass media. However, one aspect of human technical activity which has not attracted the proper attention so far, is the "electromagnetic ecology" — the influence of human activity on the state of the electromagnetic field in the vicinity of the Earth. During millions of years of existence, humanity has developed in natural electromagnetic levels of activity. Now man is beginning to alter the electromagnetic geophysical environment at a growing rate. Namely:

- An increase in high power broadcasting has taken place, particularly in the ELF and VLF frequency ranges. As a result, radio emission levels appear to be much higher than throughout history, which leads to a negative influence on flora, fauna and human health.

- The electromagnetic radiation generated on the surface of the Earth penetrates to ionospheric levels. The effects of ionosphere modification under the influence of powerful electrical transmission lines are well known. Further effects may occur due to energetic particle precipitation into the ionosphere induced by powerful radio transmissions.

- Launches of satellites and rockets are accompanied by the injection of chemicals and water vapour into the ionosphere leading to changes in ionospheric composition and associated depletion of the ozone layer.

- Acoustic waves generated during industrial explosions and military activity result in electromagnetic disturbances in the ionosphere and increased turbulence.

- Aerosols released into the atmosphere during explosions may be electromagnetically active.

- It is important to note that the influence of man-made electromagnetic fields on the biosphere may not be straightforward. Indirect coupling may occur in schemes such as the following: electromagnetic field → ionosphere → neutral atmosphere → weather → climate → biosphere.

- These processes may have been more active during the war in the Persian Gulf.

- A single event like an explosion or launch of a rocket causes a local short-lived disturbance in the electromagnetic field. In the case of repeated actions there could be accumulation effects, which could cause irreversible changes in the spectrum and intensity of the background electromagnetic field, the conditions for radio wave propagation, weather, and so on.

The study of all these effects and their ecological consequences requires coordination of the efforts of specialists in different fields and in different countries. It is of great importance to minimize negative effects on human activities.

I think it is important to assess, forecast and mitigate anthropogenic seismic or non-seismic effects on the geosphere through an interdisciplinary and multi-disciplinary approach.

I therefore propose to organize two sub-projects:

- *Artificially triggered seismicity* (ATS) led by IASPEI (Chairman, H.Gupta)

- *Man-made induced natural disasters* (MIND) led by IAGA/URSI (O. Pokhotelov)

under an umbrella project. *Geosphere response to man-made activities* (GRMA)

Proposed committee members: H.Gupta (India, chairman), D.Prochazkova (Czechoslovakia, secretary), J.Bonnin (France), P.Knoll (Germany). 1st sub-project: A.Alekseev (USSR), A.Shapira (Israel), J.Green (USA), M.Parrot (France); 2nd sub-project: P.F.Biady (Italy), O.Pokhotelov (USSR, vice-chairman). The list of Committee members is open and readers with suggestions or seeking further information are invited to contact the writer.

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(from VERSIM)

QUICKLOOK FOR VLF SPECTROGRAMS

During the recent VERSIM working group meeting at Vienna I presented an example of a VLF "Quick Look" format as currently being used by the Space Physics Research Institute in Durban. The idea is to find a means to present large volumes of VLF spectrogram data in a format which is both condensed but shows the main VLF activities (whistlers, hiss, chorus, emissions) over long periods at a glance. Moreover this format should be widely adopted by the VLF research community in order to facilitate a quick comparison of datasets from several sites covering the same period.

Previously large volumes of data were recorded on film. This method is labour intensive and expensive, although the result is a record of good dynamic range and resolution. Another printing step is required to produce hard copies of the data.

Although the following description concerns VLF spectrogram quicklooks, the basic idea of replacing analogue filming with laser printing could be used for a variety of analogue data recorded on magnetic tape.

At the S.P.R.I. a method was developed to use the high resolution of laser printers to produce grey-scaled pictures at a lower (16 grey level, 75 dpi) resolution. A hardware device (Ubiquitous Spectrum Analyser) was interfaced to a PC and condensed spectra were obtained in software, converted to laser printer format and printed. The system as it stands simply requires an operator to load a data tape, enter the tape information and press "go". (An example of a typical laser printer output was given in VERSIM.) This is a free running quick look with no timing, to obtain maximum density per page. 16 lines of 575 spectra per line, 50 points per spectrum in the 0—8 kHz range, giving a coverage of 8 hours 1 in 5 data per page.

This system attracted some interest at the VERSIM meeting, and at a later meeting between myself and A. J. Smith of BAS we decided to try to establish a common format for an international "Quick Look" system. The purpose of this article is to fathom out the interest in such a system amongst the VLF research community and to suggest a standard for such a system.

Since the existing software was developed at the S.P.R.I we are prepared to write and distribute a general user-friendly package. We assume here that any interested group will be able to use their individual hardware devices to produce a file of spectra in digital format which can be read on an IBM compatible PC, and that they will have access to a Laser Printer compatible with the HP Laserjet family of printers. We suggest the following "Quick Look" formats, to fit on American "Letter" size page (276 mm by 214 mm). The numbers in brackets refer to the format for synoptic one-in-five recordings:

- Each page of output has 10 (12) spectrogram lines of 6 (30) minutes each, in portrait mode.

- At 75 dpi and 90 spectra per minute each line will be 182.9 mm (182.9 mm) long.

- Each spectrum consists of 50 points in the 0—8000 Hz range, giving a resolution of 160 Hz per point. At 75 dpi each spectrogram is 16.93 mm high.

- Below each spectrum will be a time axis 3 mm high with the time indicated every minute and ticks every 10 s.

- The total height of each spectrum and axis will be 19.93 mm, which will fill 199.33 mm (239.2 mm) of a page leaving room at the top for one line of header.

- For continuous recordings, one hour of data fits on one page and will always start on the hour. For synoptic recordings, six hours fit on one page and will always start on hour 0, 6, 12 or 18. Multiple files of various lengths will be handled in software.

- Timing will be simple and depend only on the known start time of data files and the period between spectra.

This is the "standard" format. Different formats can be easily achieved by changing the time between spectra. To identify whistlers on the traces we suggest 180 spectra per minute (3 Hz) giving about 6 spectral lines per whistler or about 2 mm, which is just enough for identifying whistlers. The spectra per minute parameter will be an input parameter and any value is allowed; however not all values will give an integral number of minutes per line. Only the main format (540 spectra per line, 10 lines per page for continuous, 12 lines per page for synoptic, 50 points per spectrum) remains fixed.

We would like to ask anyone interested in this system to comment on the suggested format and to indicate their participation in this scheme. Please send me your suggestions to the address below. Once the overall format is agreed on, we will suggest a suitable file standard for the digital spectrum data: any suggestions in this area are also welcome (ASCII, Fortran, Pascal or 'C'?).

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(from VERSIM)

THE DEVELOPMENT OF RADAR IN NEW ZEALAND IN WORLD WAR II

In the 1990s radar as an essential aid to navigation in the air and on the sea is so commonplace that it is difficult to realise that in the mid 1930s, less than sixty years ago, it was a completely new technique that was being hastily developed in the greatest secrecy by the chief combatants of World War II – Great Britain, Germany, the United States, Japan, France, Italy and the Soviet Union. Although the concept of detecting the presence of an aircraft or ship through measuring the delay of a radio signal reflected from it back to the position of the transmitter was not new, it was only in the mid thirties that research and development began in these countries in earnest. Considering the effort that was being put in the development of radar in the three or four years immediately prior to the outbreak of World War II, it is amusing to realise that a German inventor had been granted a patent covering the basic idea of radar in 1904[1], and that Marconi in a speech to the American Institute of Engineers in 1922 said "... I have noticed the effect of reflections of these (radio) waves by metallic objects miles away ... it should be possible to design apparatus by means of which a ship could radiate ... in any desired direction, which rays, if coming across ... another ship, would be reflected back to a receiver screened from the local transmitter ... and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather.[2]" The Americans Breit and Tuve in 1926 first used pulse radio transmissions to determine the source of a distant object, in this case the ionosphere[3], while in 1928 a patent for "..... methods and means for determining the positions, directions and distances of objects by wireless waves, applicable to navigation and for the location of dangerous objects or enemy craft" had been granted to Salmon and Alder of the Royal Naval Signal School in England[4]. Had these ideas been followed up at the time, the history of radar development would have been vastly different from what actually occurred.

It is not the purpose of this article to say anything about the development of radar in different countries apart from those that had a direct effect on the work in New Zealand, as the topic has been covered in numerous publications[5,6]. Not surprisingly, since New Zealand was a member of the British Commonwealth, it was from Great Britain that the initial information on radar development came. It arose in the following way:

Early in 1939 when it was recognised that war was imminent, the British Secretary of State for Air asked that a physicist be sent to England (along with other Commonwealth representatives) for training "in an entirely new scientific technique of a defence nature". The reasoning behind this was that Great Britain in 1939 was putting all its effort into building radar for its own needs, so it would be necessary for Commonwealth countries to devise their own, at least initially, and each build up a team who could in due course assist in the introduction of radar systems as and when they became available. Thus did one physicist in each of a number of Commonwealth countries learn the basics of radar as it had been developed in Great Britain up to the time of the outbreak of World War II. The New Zealand representative was Dr. (later Sir) Ernest Marsden (the Marsden who with Geiger performed the crucial experiments in Rutherford's laboratory at Manchester that led to the discovery of atomic structure).

New Zealand was lucky to have a person of the calibre of Dr. Marsden to send to Great Britain. As head of the NZ Department of Scientific and Industrial Research (DSIR) he had the authority to establish a research and development programme immediately on his return from overseas. In England he was able to secure a number of critical components, virtually unobtainable in New Zealand, such as coaxial cable, oscilloscopes, a Pye television receiver (actually two), and an incomplete 1.5 metre ASV (Air to Surface Vessel) radar, which had just been developed for the British Royal Air Force. He was able to establish a permanent arrangement in England for a continuous flow of highly classified technical data on radar developments and operations, and a fund which ensured that a supply of components otherwise unobtainable in New Zealand were available (when they could be spared) for radar development.

New Zealand, then as now, was a small country in a vast ocean, isolated from the rest of the world, with a long coastline. It was clear that the chief danger would be from enemy submarines and raiders, and possibly warships. The need was therefore to detect surface vessels from land, sea and air, and provide gunnery and searchlight control for the cruisers of the New Zealand Navy and coastal batteries guarding the main ports. By early 1940 developments were under way for all these purposes.

The highly secret programme was begun in two locations. One was the Radio Section of the NZ Post Office (in Wellington), at that time the organization in the Civil Service most advanced in electronic techniques. Two Post Office engineers were allocated part time to the work, and two or three technicians. The other location was a high-security laboratory in Canterbury University, Christchurch, under physics professor F W G White (later Sir Frederick White, head of the Australian CSIRO). To both these laboratories DSIR scientists were seconded in slowly increasing numbers – initially D M Hall in Christchurch and C. N. M. Watson-Munro (later Director of the Australian Atomic Energy Commission and professor of plasma physics, University of Sydney) in Wellington. The two teams were given different objectives by Dr. Marsden. That in Christchurch was given a self-squegging transmitter, an IF strip from a Pye television receiver and some high frequency valves, and was asked to develop ship-borne radar for the detection of both aircraft and ships, and to direct naval gunfire. The

Wellington team were to develop radar sets for coastal locations to detect shipping, an airborne set for the same purpose (ASV), and to provide precision radar for the fire direction of the 150 mm batteries guarding New Zealand's main ports.

Also in late 1939 it was arranged that a special one-year course in radio physics be established at the Universities of Auckland and Canterbury, open to recent physics graduates or those taking their final year in a BSc course. (The author of this article was one of the 1940 class at Canterbury.) By this means the number of physicists and engineers actively working on radar in Wellington had risen from three in January to nine in December 1940, although the Christchurch group remained at two physicists, an engineer and two technicians.

Both the teams in Wellington and Christchurch faced daunting technical problems in developing novel techniques far from the help of their more advanced colleagues overseas, and with minimal library back-up restricted to the small amount of information that Dr. Marsden had been able to bring with him from Great Britain, and the trickle of new information that spasmodically appeared.

However, in spite of these disadvantages and the small number of people involved, the work achieved in that first year was remarkable. The first radar echoes were seen by Watson-Munro from the top floor of the Wellington Post Office building at the end of 1939. The receiver used an IF strip from a Pye television receiver and the transmitter was a self-squegging oscillator on 183 MHz using a pair of RCA 834 valves in push-pull with separate receiving and transmitting antennas each consisting of a centre-fed dipole and reflector. The transmitter produced 2 microsecond pulses at about 1 kW peak power, and was the basis of all the land-based CW (Coast Watching) and gunnery control CD (Coast Defence) radars until around mid 1941 when the more powerful VT90 "micropup" tubes became available.

Between January and June 1940 the staff in Wellington had increased by four (E. R. Collins, later professor of physics at Auckland University, K. D. George, I. K. Walker, subsequently assistant Director-General of the NZ DSIR, and C. H. Vincent). The main effort was put into designing receivers, broadside antennas and displays for the various radar systems. The task was simplified by the fact that all of them except that for naval gunnery (see below) operated close to 200 MHz so only one design of transmitter and receiver, and antennas to some extent, served all needs. By the middle of 1940 a CW set was operating for the Navy at Auckland, an airborne ASV was under trial, and an experimental air and surface warning set was operating on the cruiser HMS Achilles. By the end of the year CD sets were operating for the Army at coastal batteries at Auckland and Wellington, three CW sets for the Navy on the approaches to Auckland and Lyttelton, and an experimental early warning and gunnery control set on HMS Achilles.

Further development and refinement of these early sets continued through 1941, but in the second half of that year there was a major change in administration. Whereas the DSIR staff had been primarily responsible for research and development, and the Post Office for construction of radar sets, the whole of the programme was now put under the control of DSIR. The Radio Development Laboratory (RDL) with Watson-Munro as director, was formed as a branch of DSIR to carry out the programme. Professor White had at this time been loaned (subsequently permanently) to Australia and his Christchurch unit was put under the control of RDL. Dr. O. O. Pulley (on loan from Australia for a year in exchange for Professor White) took over as director until October 1942 while Watson-Munro was in the USA (see below). In June 1944 Watson-Munro was replaced as director by I. D. Stevenson, who was in turn replaced by J. B. C. Taylor in September 1945 until RDL was wound up in 1946. Early in 1942 RDL moved from Post Office quarters to its own premises and staff members increased rapidly, reaching 100 of all ranks by the end of 1943, including 29 physicists and 11 engineers.

COAST WATCHING (CW)

The New Zealand Navy with responsibility for coast watching, required a number of simple radar sets, capable of being installed on remote hilltops (often without road access) and offshore islands, and powered by small generators. This requirement resulted in the set shown in Figure 1A. As mentioned above, the transmitter (Figure 1B) consisted of a squegging oscillator using a pair of RCA 834 tubes in push-pull and generating a 2 microsecond pulse of around 1 kW.

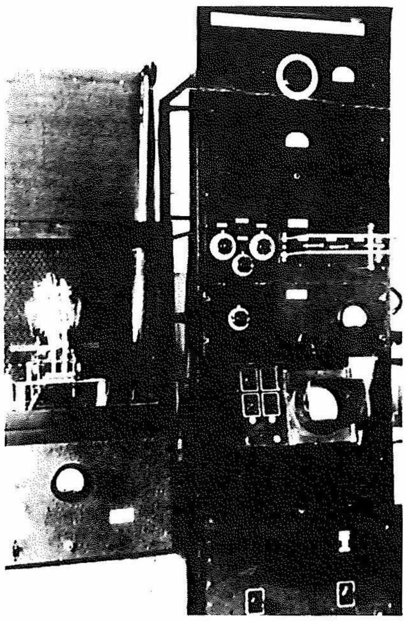


Fig. 1A. CW Radar — transmitter on left, receiver and display on right.

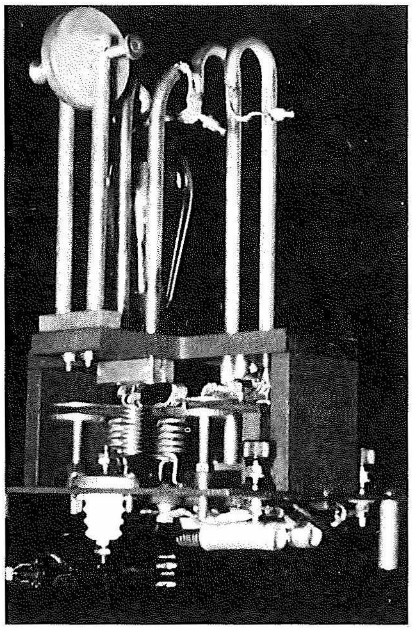


Fig. 1B. Early CW transmitter with one RCA 834 tube removed.

The pulse triggered a simple time base on a 15 cm CRT, and echoes deflected the spot at right angles to the trace. The transmitter pulse also kicked into operation a critically damped oscillator on 82 kHz, from which after amplification and differentiation range "pips" were provided at 2000 yard intervals which deflected the CRT spot in the opposite direction to the echoes. This "A display" was universal on radars in service in all countries at this time. The antenna consisted of stacked horizontal dipoles backed by a mesh reflector, with the centre two of four stacks used for transmitting and the outer pair for receiving. The original CW set was powered by petrol engines charging 24 volt batteries, with a rotary converter to 230 volts AC. The petrol driven 230 volt alternators that followed proved unsatisfactory for continuous service and were later replaced by diesels.

The CW sets were capable of being transported by sledge dragged by a bulldozer. Accommodation for the naval crew was built close to the radars, so the total amount of construction required to set up even a simple CW station was considerable. It was carried out by the Public Works Department and there are hair-raising tales of getting machinery and equipment ashore on some of the islands or remote capes on the mainland. Subsequent fuel supplies were at times brought in by packhorse. The first CW sets had the broadside antenna mounted on the side of the radar hut, and the hut itself was rotated to scan in azimuth. Control was manual, and in a high wind the operator had to call for assistance to achieve an azimuth scan! Later sets had a separate antenna and control was electromechanical, but the antenna was fed by flexible coaxial cable, which meant there were strict limits to the range of azimuths that could be scanned. Wear and tear on the gear boxes and the operator's nerves in the frequent gales was severe and the occasional disaster occurred. The total area of a broadside antenna approached 20 m^2, and the reflector was 50 mm wire netting, so the loading in a high wind was considerable.

The radars were initially set up on site by physicists and engineers involved in the design and construction, and the Navy crew trained in operation and maintenance. The latter was helped by the fact that they had been given a special course on radar (initially by an ex-science teacher recruited by DSIR) at the Naval Radio Training School in Auckland.

With the RCA 834 transmitting tubes ranges up to 25 to 30 km on a 10,000 ton freighter were achieved. With the more powerful GEC VT90 "micropup" tubes installed from mid 1941 ranges over 40 km and sometimes approaching 50 km were obtained from the higher elevation sites. Early in 1942 a CW set was installed on Mbengga Island covering the approaches to Suva, Fiji's capital and main port. (The radar site was on the 360 m summit of the trackless jungle-covered island, and *everything* had to be hand-carried from where it was landed on the beach - quite an operation!). Overall the simple CW radar sets did great service, and the programme was fully justified by the audacious activity of German raiders around the New Zealand coast(7).

In 1943/44 these simple CW sets were phased out, and replaced by more sophisticated microwave sets (see below).

COASTAL DEFENCE (CD)

Range-finding for the guns defending the main ports of Auckland, Wellington and Lyttelton was by "depression range-finders" (effectively an optical base equivalent to the height above sea level) which were, of course, valueless in fog or darkness. The development of a radar for fire control was urgent, and started at Wellington early in 1940. The transmitter/receiver/display combination of the first set was identical to the CW, except that the time-base was displayed on a 30 cm cathode ray tube. In order to obtain good directivity the first CD set (installed at the Motutapu battery near Auckland) had separate 4-stack broadside antennas for transmitting and receiving. They were mounted on the sides of two manually rotated huts which were turned in synchronism by the operators communicating with each other by telephone! In 1941 the transmitter of this set was moved into the receiving hut and connected to a Yagi antenna, simplifying the operation enormously.

The first CD set for Wellington's Palmer Head battery was installed, without significant trials, in a tiny enclosed space at the fort, and after a few days continuous operation it overheated to the extent it became unusable! The design team had to devise better cooling, and learnt the bitter lesson of the need for robustness in military equipment, and the (not unreasonable) unforgiving attitude of military personnel to defects in equipment they are expected to use in action.

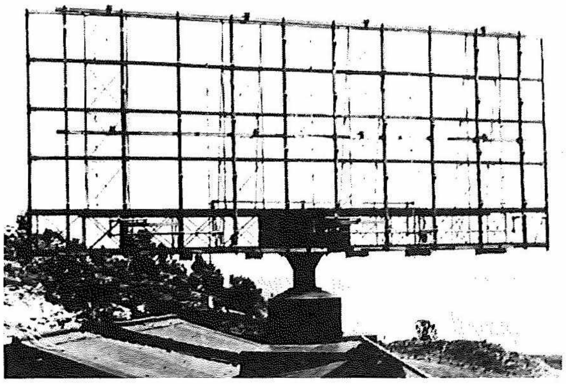
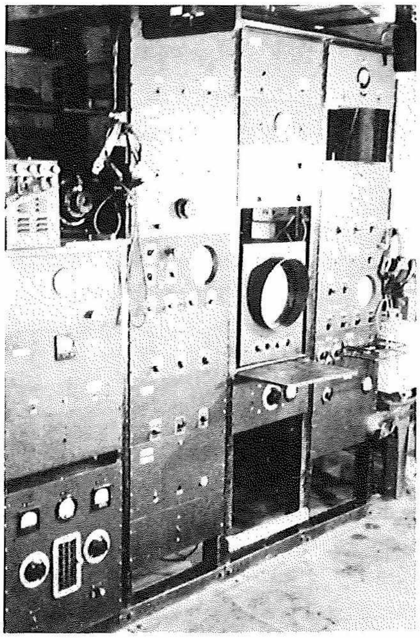


Fig. 2. 5-stack broadside array.

The closeness of the Palmer Head battery to the Post Office laboratory in Wellington allowed more thorough experimentation with antennas than had been possible at Auckland. In both places this had to be confined to daytime to allow radar operation at night, which did not help matters. The ultimate design reached by late 1940 had the three centre stacks of a five-stack broadside array for transmitting and the outer pair for receiving (Figure 2). The relative phasing of the latter was alternately switched between two different values causing the antenna beam to swing backwards and forwards in azimuth by 6 or 7 degrees. On the display the timebase was moved a small amount laterally in synchronism, so a pair of target echoes appeared side by side, and then the antenna azimuth was adjusted until they were of equal amplitude. With an effective horizontal beamwidth of 10° an operator could thus read azimuths to better than a quarter of a degree under good conditions.

During 1941 a number of improvements were made to the CD radars. The VT90 transmitter and a much improved receiver with coaxial resonator tuning on the RF and local oscillator stages became available, and two 15 cm CRTs were added to the display. One had a selectable expanded section of the timebase for accurate ranging and the other displayed the split target echo while beam switching. A much sturdier and more powerful antenna rotating system, designed by the Christchurch branch of RDL and the Public Works Department, also became available and allowed satisfactory operation even in a considerable gale.

The improved set was installed in stages at Palmer Head through the middle of 1941, while a second (originally intended for Motutapu) went to a coastal battery guarding Suva in Fiji after Japan entered the war. Further sets were made by industry (Figure 3) largely in Wellington, but not without problems as the experienced radio engineers discovered the wide differences between so many circuits in radar and those in radio communications. In all eight CD radars were supplied to the Army, the remainder of New Zealand's needs being met by the purchase from Australia of ShD (Shore Defence) gunnery control radars which also operated at about 200 MHz. Eventually these sets were replaced in 1944 and 1945 by the CD Mark 3 microwave radar manufactured in Great Britain.



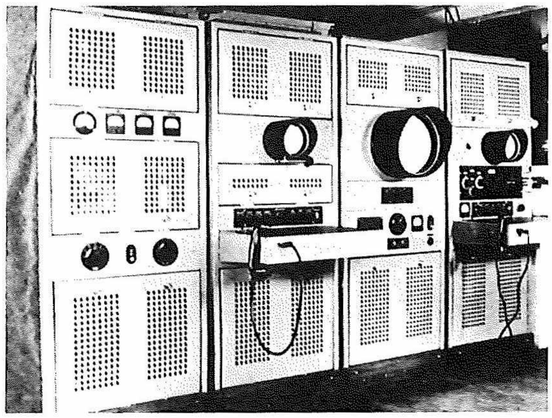


Fig. 3. CD Radar — Laboratory model (upper) and final version (lower).

Unlike the Navy, the Army initially relied on the DSIR to train personnel to operate and maintain the sets. After recruiting to cover the needs of established technical services the Army then selected those they thought might be suitable to handle what was to them a new-fangled device of uncertain capability. The author of this article had the experience of training two such far from ideal groups at Palmer Head; it was noticeable that the second was of better quality than the first as the Army got more faith in the "hurdy-gurdy"! The training problem eased substantially from the middle of 1941 when the first Service graduates who had been through the special university radio physics course appeared on the scene.

SHIP WARNING GUNNERY (SWG)

When the pocket battleship Graf Spee was scuttled in the River Plate estuary in December 1939, the aerials of the radar set designed to direct the fire of the ship's guns were plain to see[8]. It turned out later that a lucky hit had disabled the radar early in the action, which had enabled the New Zealand cruiser Achilles and HMS Ajax, with no radar themselves, to manoeuvre safely hidden by smoke screens between brief appearances to fire on the battleship. A young RNVR lieutenant on Achilles, S D Harper (in peacetime a research worker at the British Post Office electronics laboratory), realized how narrow had been the cruisers' escape, and resolved that his ship would not fight the next action blind. He prevailed on the Wellington Navy Office to second him to Professor White's team in Christchurch to design and build a radar set capable of directing the fire of the ship's main armament.

As an interim measure an experimental radar was hastily assembled in Christchurch and Wellington and installed on Achilles in July 1940 while Harper started his own design. With experience in both electronics and servicing ships at sea he rejected the "rack and panel" construction used by the Post Office and adopted a filing cabinet principle with sliding drawers that pulled out on trailing leads. By putting wiring on top and valves underneath inspection and servicing could be carried out with the equipment operating. This revolutionary design was highly successful, and was adopted as standard by all wartime radars subsequently built in New Zealand. To ensure accurate ranging he used a crystal controlled oscillator at 164 kHz (providing 1000 yard range markers) and divided down to 2050 Hz to trigger the transmitter pulse and generate a timebase. The frequency was 430 MHz (wavelength 70 cm), the highest that could be practically attained with components available in New Zealand at the time, and the antennas a pair of multi-element Yagis mounted on robust shafts of galvanised water pipe. Two sets of this design were built in Christchurch and installed on the NZ cruisers Achilles and Leander in 1941 with the antennas on the fire-control tower. With a ship range of 7000 yards (against less than 5000 yards on the experimental model), range accuracy of 50 yards (500 yards) and quoted azimuth accuracy of 1°, they were a vast improvement on the experimental model[9]. Both sets operated successfully until replaced by production models (see below).

In 1941 as the Japanese threat developed the British Admiralty enquired of New Zealand whether radar sets could be manufactured for the Eastern Fleet based in Singapore. Five air warning (SW) based on the CW design and five SWG based on the Harper design were promised. Later the SW order was cancelled, but the SWG order increased to 30, although only 24 were ultimately delivered, including eight to the New Zealand Navy. To attempt such production on an urgent basis required vast effort which was based at a subsidiary RDL laboratory at Auckland and local industry engaged to manufacture. Improvements included increased transmitter power using VT90 "micropup" tubes, a display with range "pips" in a "ruler-type" arrangement less prone to reading errors, and capability to show a selected portion of the timebase on an expanded scale for accurate ranging. In spite of delay in supplies, the first set was delivered in February 1942 and the remainder by the end of the year. Of those dispatched first to Singapore and later to Tricomalee in the Indian Ocean there is reason to think that one at least fell into Japanese hands, complete with its manuals; sadly there seems to be no record of any of them being installed.

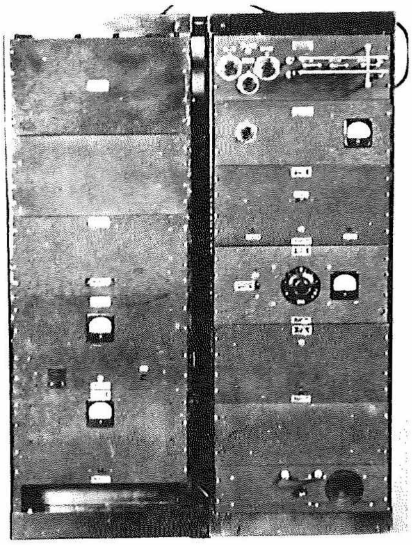
WORK FOR THE ROYAL NZ AIR FORCE

On his return from England in October 1939 Dr. Marsden had with him an incomplete ASV (Air to Surface Vessel) radar. A receiver was added by the group in Wellington and early in 1940 New Zealand's first airborne radar was flown in a Waco aircraft. It had a range of 20 km on the 5000 tonne inter-island ferry Rangatira. Subsequent development was based in Christchurch with Professor White's group and a special Air Force unit, and a set produced along the lines of the British ASV Mark I[10]. This used the squegging oscillator principle for the transmitter at about 200 MHz and B-scope display. The transmitting antenna gave a fan-shaped forward-looking beam and two receiving antennas were arranged so the echoes from each would be of equal amplitude only when the target was dead ahead of the aircraft. A rotary switch connected the two antennas alternately and the echoes deflected the CRT spot to the left and right of the vertical time-base.

The transmitter and receiver of the CW and CD radars were adapted for use in aircraft, and the first set installed in an Oxford gave ranges approaching 30 km on the Rangatira. About 20 ASV sets were produced by the Post Office Workshops in Wellington and Christchurch and installed in Vincent and Oxford aircraft up to October 1941. Further development ceased when the better-performing British ASV Mark II became available from July 1941.

The wide use of the ASV Mark II in New Zealand and the Pacific necessitated the provision of ASV beacons to assist aircraft to return to their home or Allied base. These were designed by the RDL and RNZAF units in Christchurch, and transmitted a coded response via an all-round-looking antenna after triggering by an ASV signal (Figure 4). The beacons for the Pacific Islands were "tropicalized" to ensure that the electronics would stand up to the humidity and moulds that would be encountered. Their performance over average ranges of 100 miles was equal to that of the US sets bought later[11].

Whereas in Britain defence from air attack was the top priority, in New Zealand it was of less importance than coast defence until late 1941 when Japan entered the war. How-



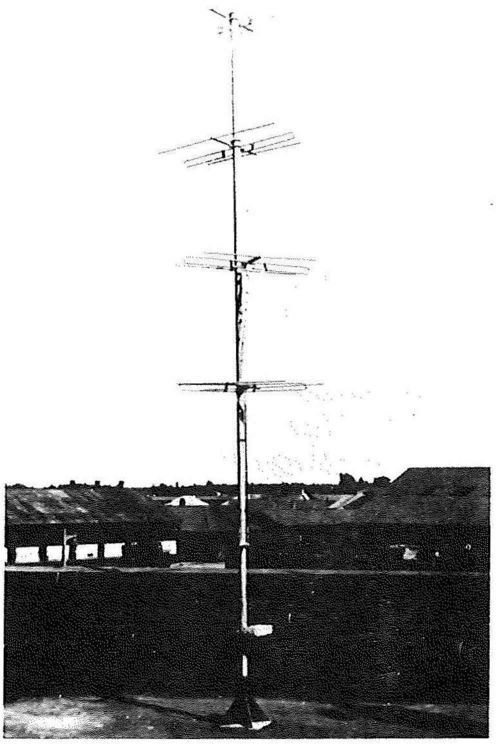
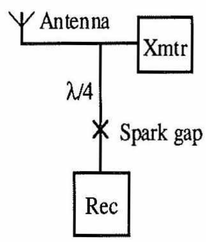


Fig. 4. ASV Beacon. Responder (upper) and antenna (lower).

ever by this time ground radar for RNZAF needs had already been ordered from Great Britain, and RDL involvement was limited to assistance in the installation where necessary, and sometimes the supply of alternatives to missing parts. An overseas version of CH (Chain Home), COL (Chain Overseas Low) and GCI (Ground Controlled Interception)[5] were involved. An old COL, previously used for training purposes by the Air Force, was installed on Malolo Island off Nandi Aerodrome in Fiji in February 1942, and several COLs by the Air Force in the Solomons in 1943.

Of particular interest was the fitting of the first successful T-R (Transmit-Receive) system in New Zealand to a CH radar on the Coromandel Peninsula. In this system a single antenna is connected to both the transmitter and receiver. A spark gap at an appropriate point across the transmission line protects the receiver when the gap fires during a transmitter pulse. The system used a locally made spark gap, and did away with the necessity of providing a receiving antenna on a separate mast.



In early 1943 as the Allied operations in the south Pacific turned more to the offensive, RDL gave further assistance in setting up a GCI radar in Guadalcanal in the Solomons. As a result of this experience it was recommended that the set would be much more useful if mobile. Following a request by Admiral Halsey, the Allied Commander in the South Pacific, two sets were each put in a 6-truck convoy by RDL. The first was set up at Munda in the Solomons by the RNZAF in September 1943, and the second on Bougainville. The pressure ventilation incorporated in the operating trucks proved to be a real boon in the tropics.

MICROWAVE RADARS

In 1939 it had been appreciated in Britain that metre wavelength radars would never be satisfactory for night fighter aircraft to engage an enemy bomber, both because of the extra drag and the lack of precision in azimuth that was achievable by practicable antennas. Research into methods of producing useful power at a wavelength of 10 cm, and of detecting such waves, was started late in 1939. By the middle of 1940 the cavity magnetron was producing powers of several kilowatts at this wavelength, and the klystron used as a local oscillator enabled their successful reception. Microwave radar was possible, and within months its enormous potential on land, sea and in the air was being realised. It is now history that the secret of microwave radar was taken to the USA in October 1940. In a far-seeing move the US authorities set up the Radiation Laboratory of the Massachusetts Institute of Technology (MIT) to develop and exploit the new technique, and at the same time to gear industry to manufacture on a large scale. Another important device that had been invented in Great Britain in May 1940 was the Plan Position Indicator (PPI) display, originally developed for the GCI radar[12] which had a "rotating coupler" in the transmission line to the antenna allowing it to rotate continuously. In the PPI display a radial time-base rotates (in synchronism with the rotation of the antenna) from the centre of a CRT and

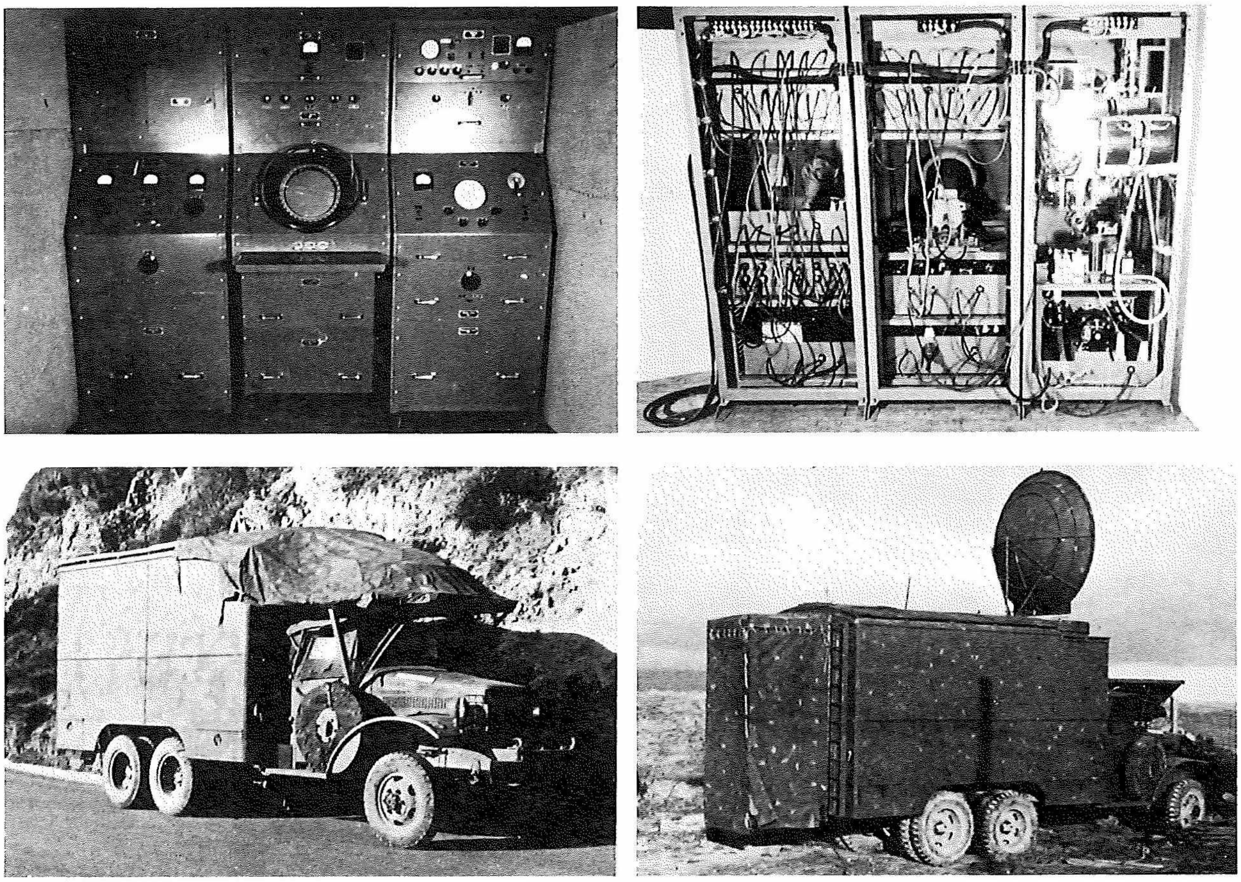


Fig. 5. Microwave Radar. Front view (top left). Rear showing trailing leads (top right). Radar truck with dish antenna stowed for transport (bottom left) and with antenna in operating position (bottom right). The interior of the truck showing this equipment appears on the cover of this issue.

is brightness modulated by the echo signal and, when required, range markers. In this way a map of the area surrounding the radar is presented, from which the azimuth and range of the desired target, appearing as a short arc, may be pinpointed. The PPI display enabled the full potentialities of microwave radar to be realised, and, with its derivatives, is at the heart of every modern radar alongside the cavity magnetron.

Late in 1941 Watson-Munro was appointed "Scientific Liaison Officer" (SLO) at the New Zealand legation in Washington DC with the prime objective of learning microwave techniques at MIT and obtaining a supply of critical components. He returned in May 1942 with magnetrons, klystrons, parabolic aerial dishes etc. supplied by the USA and Canada under "lend lease". With the subsequent permanent appointment of a Washington SLO (one also in London) the continued availability of these critical components in New Zealand was assured, and enabled a vigorous programme of development and construction of microwave radars to be maintained. Almost as important, the subsequent flow of technical literature, originating in both Great Britain, the USA and Canada, was ensured, relieving the semi-vacuum in library facilities that had existed in the early days at RDL. The magnetrons originally brought to NZ by Watson-Munro were designed to operate at 9.2 cm, a wavelength that was maintained in all microwave sets built in New Zealand in World War II. To help build up the nucleus of a team two RDL physicists spent a few months in Australia where microwave work had already begun.

In a far-seeing move it was decided very early in the microwave programme that a mobile coast-watching and surface fire control radar be designed with the thought that it could be available for service anywhere in the Pacific, and be operational within a few minutes upon a chosen site. Even with the critical components available the amount of design and development work involved for the first microwave radar was enormous – all the RF components such as coaxial transmission lines (there was no experience in waveguide theory and practice in New Zealand at the time), rotating coupler, T-R system etc., spark-gap modulator, a PPI display and so on. In the middle of 1942 the state of the war in the Pacific demanded the greatest urgency and with the recruitment of local industry in Wellington and Christchurch, and the Electrical Engineering School at the University of Can terbury, the first mobile microwave radars were in full production early in 1943 following the firing up of the first pre-production model at RDL on Christmas Day 1942. Because the radars were to operate as mobile units in the Pacific the normal standard component and chassis assembly was modified to increase robustness and resistance to vibration, and all the electronics were "tropicalized".

The radar itself was mounted in a ten-wheeler truck with the antenna dish on a rear platform initially, but in later models on the roof of the cab to allow a larger radar cabin with room

"in the first half of 1943, the mobile microwave sets produced in NZ were well ahead of contemporary efforts by the USA and Australia in the South Pacific"

for a plotting table and communications (Figure 5). A second truck contained three petrol generators (later two Lister diesels) with a workshop bench and tools. A supply of hand tools to enable first- or even second-line servicing in the field was considered essential, and, to ensure that the initial production run of 12 sets was fully supplied, late in 1942 two of the office staff of RDL visited *every* hardware shop in New Zealand and virtually exhausted their stocks of these items! Plenty of spare parts and essential electronic test gear such as oscilloscopes, standing wave detectors, test oscillators, vacuum tube voltmeters etc., designed at RDL were also sent out with each radar set.

After assembly and installation in the trucks by RDL staff the radars were fully tested in rough conditions by driving up river beds, and setting up and operating on various coastal sites. Results were highly satisfactory, well repaying the hard work that had gone into their production. After arriving at a *level* site the radar could become operational in no more than ten minutes, but up to 30 minutes if significant jacking up of the trucks to level them was required. There is no doubt that, in the first half of 1943, the mobile microwave sets produced in New Zealand were well ahead of contemporary efforts by the USA and Australia in the South Pacific. Early in 1943 the first truck-mounted microwave radar saw service in the Russell Islands in the Solomons, in the defence of a US motor torpedo boat base. An RDL scientist and a NZ Navy lieutenant were seconded to serve with the US 3rd Raider Marines, controlling the fire of a battery of 155 mm mobile guns ("Long Toms"). Further mobile microwave sets, manned by the NZ Navy, were sent to other points in the Solomons in April and June, in support of both the US and NZ forces operating in the area. Other RDL scientists visited some of these radars in operation, ensuring that lessons learned in the field and improvements and adaptations foreseen as desirable were incorporated where possible in later models.

As well as seeing service in the Pacific, the microwave radars gradually replaced a number of the 200 MHz CW sets in New Zealand from late 1943. Four sets were constructed for minesweepers operating in the Pacific Islands, their design and fitting requiring detailed planning because of space limitations. A bridge-mounted PPI display (now standard practice on virtually every radar-equipped vessel afloat) allowed the navigator to have ready access to the screen. Several of the CW microwave sets were re-modelled for detection of low-flying aircraft and truck-mounted for mobile operation by the British operating from India, but never saw service before the war's end. The last microwave radar designed at RDL was for height finding, and used for tracking radiosonde balloons by the Meteorological Service. Six of these sets were built and continued in operation until the last was replaced in the early 1960s.

LONG-RANGE AIR WARNING (LRAW)

Following the landings of US Marines in the Solomon Islands in the middle of 1942, it became apparent that there was a need for a long-range air warning set that could be quickly deployed after a landing. The transportable US air warning radar (SCR 270) took up to three days to bring into operation, whereas air warning was required virtually immediately following a landing.

In 1943 a radar operating at 100 MHz was designed, and, again with the help of industry, the Public Works Department and Canterbury University Engineering School, six were produced in a remarkably short time. As with the microwave equipment the sets were truck-mounted — the first of three trucks contained the radar equipment and a demountable moderate gain Yagi on the roof, the second contained two diesel powered generators and workshop facilities, and the third contained components for a high-gain broadside array and its mounting tower. Following coming ashore in a landing craft and being driven to the site, the radar could be brought into operation using the Yagi antenna (Figure 6) in about half an hour. It took about a

Fig. 6. LRAW radar truck with Yagis erected.

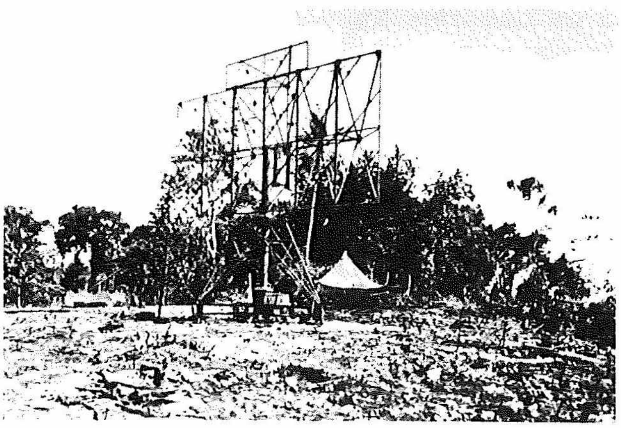


Fig. 7. Broadside array (replacing Yagi in Figure 6) in operation.

day to erect the broadside array (Figure 7). Ranges of 150 to 200 km on aircraft flying at 3000 m were normal.

The LRAW sets were assigned to US Navy "Argus" units with an RDL physicist (temporarily seconded to the NZ Army), who had been closely involved in the assembly and testing, accompanying each one to train the Argus personnel in operation and maintenance and take part in its use in military operations. The first LRAW was dispatched from New Zealand in December 1943, and took part in the landings on Nissan Island in the Solomons in February 1944. It performed extremely well and received much favourable comment from the US Command [13]. Other sets went to Emirau Island (Bismark Archipelago), Peleliu (Palau Islands) and Ulithi (Pacific Islands Trust Territories). In all cases the performance was good, allowing for deficiencies in siting in some cases, and the decision to have an RDL expert in charge, who was determined to get the best out of the set, was amply justified.

ASSISTANCE TO ALLIED OPERATIONS IN THE PACIFIC

Although not strictly within the topic of this article, the development of radar in New Zealand, another important activity of RDL scientists, in 1942 and 1943 particularly, was the fitting of US manufactured radar sets on to so-called attack transports. These sets, in ex-factory packaging, were hoisted aboard as these ships left USA shores, the intention being to fit them at the earliest opportunity, which in some cases turned out to be a short stopover in New Zealand. At this time there were very few US radar experts in the South Pacific, whereas the RDL scientists with experience of designing and building radars from first principles and installing them in ships, were ideally suited to undertake the installations. It was not unusual to be faced with a previously unseen radar set, complete with manuals, and to be asked to install it in five days while the ship was in dry dock! It was demanding and exhausting work, but of great value to the US forces. For example, all the attack transports for the landings at Tarawa in the Marshall Islands (now Kiribati) were fitted with radar in this way at the Wellington floating dock. There were installations on many other US vessels, and a T-R system was devised for the antennas of a Dutch cruiser operating with the Allied navies in the South Pacific.

Until late 1943 little was known of Japanese radar in the Pacific, but in November of that year much evidence came in that they had a variety of both land-based and seaborne equipment. An active countermeasures programme was needed, and a new headquarters unit to coordinate Allied countermeasure activities in the area was formed, which included personnel from all the Allied countries operating in the Pacific theatre of war[14]. Two RDL scientists were seconded to this group in December 1943, operating from New Caledonia and the Solomon Islands, and subsequently from New Guinea, Morotai and the Philippines. Their activities included intelligence, accompanying missions for radar search and destroy, and jamming enemy radar on raids to major targets, and continued until the war's end in August 1945.

SUMMARY

From small beginnings late in 1939 New Zealand was able to develop radar sets of increasing sophistication throughout World War II and put them in the field in New Zealand and the Pacific sometimes well before sets of similar capability could be made available from elsewhere. Because of limited facilities mass production was not attempted, but with the very full cooperation of local industry, small numbers of radars incorporating new applications were produced in a very short time between concept and placement in the field. This achievement was all the more meritorious as there was no television industry as a basis, and no one, at least at the outset, trained in any way in what was an entirely new invention. In all, 117 sets of many different types were delivered to the Armed Services, including 76 to the Navy and seven to the US Forces in the Pacific[15].

Articles, long or short, learned or off-beat (see THE BACK PAGE), News or Views, Letters or Guest Editorials are all welcome. Please submit directly to the Editor-in Chief or through one of the Editors listed on page 2. Plain text sent by email is fastest and most convenient to the Editor, but send print-out or disk (see Editorial for optimum) if you include mathematical equations. Photographs or other graphics (line drawings) are wanted for most articles at the rate of about one or two per printed page. These should be in the right size for printing without scaling.

RDL personnel in New Caledonia, January, 1944. From left: S. E. Slatter, the author, E. R. Collins, and C. N. Watson-Munro.

It should be stressed here that no equipment put into the field was complete without detailed operational and maintenance manuals. The writing and printing of these was a demanding job, and in many cases the only people who could supply the basic information were already heavily committed to furthering other urgent work. This sort of thing is only one example of the dedication of staff to the radar development programme, and their willingness to work long hours when necessary under conditions which were often far from ideal. Even so, the job had its lighter moments — examples of these could fill a book. Like the operator at Motutapu who missed reporting the liner Queen Elizabeth anchored 2000 yards from the front door – "Sorry, sir, I thought it was an island", or the pilot's comments about a radar operator whose ASV set had the left/right antennas connected right/left to the display, or the interference from a microwave transmitter under test causing an irate citizen from next door to the RDL building to complain that he was nearly blasted out of the room when he was listening to Christmas carols on the radio, on Christmas Day too! The list is endless, but unfortunately not for this article.

It would be appropriate to end this brief account of the development of radar in New Zealand with an acknowledgement to the late Sir Ernest Marsden, who launched the programme in 1939 and by his continued enthusiasm and encouragement did a great deal to ensure its success. Sir Ernest believed that "all an administrator could really do was to create the atmosphere in which research could take place, to stimulate his officers with ideas and to see that they had adequate facilities"[(16)]. He did this to great effect in the radar development programme in New Zealand. His contribution to this development, and through it to the war in the Pacific, was very great and should always be remembered.

ACKNOWLEDGEMENTS

In the preparation of this article I am indebted to a number of my former colleagues in the Radio Development Laboratory who have provided information on their personal experiences, refreshed my memory on many aspects of the programme that had escaped me after a lapse of fifty years, and provided comments and criticism on the draft manuscript. I K Walker provided an excellent report on the CW, CD and SWG programmes, while E. R. Collins covered a great deal of the earliest days in 1939 and 1940. Others who should be mentioned include, in alphabetical order, I. D. Dick, A. D. Gifkins, C. G. Liddell, Prof. A. G. McLellan, N. B. Manssen, S. E. Slatter and Dr. R. M. Williams. I would also like to thank Bruce McMillan of Eclipse Radio and Computers in Dunedin, whose recent research into the history of the World War II radars guarding that port has turned up much useful information from the wartime records of the Public Works Department and the Services, and which he has made freely available to me.

REFERENCES

1. Price, A., 1967. "Instruments of Darkness", William Kimber, London, p. 56.
2. James, R. J., 1989. *IEE Review*, October, p. 343.
3. Breit, G., and M. A. Tuve, 1926. *Phys. Rev.*, **28**, p. 554.
4. Rawlinson, J. D. S, 1985. *Proc. IEE*, **132A**, p. 441.
5. Cockroft, J. D. and others, 1985. *Proc. IEE* Special Issue on Historical Radar, **132A**, No. 6.
6. Price, A., 1984. "The History of US Electronic Warfare, Vol. 1". The Association of Old Crows, USA. This book contains useful summary accounts of the development of radar in the USA, Germany and Japan.
7. Norris , B., 1991. "Germans Laid Mines off Lyttelton in 1941", *The Press*, Christchurch, NZ, 24 August.
8. Price, A., 1967. ibid., p.17.
9. Burbidge, P. W., 1952. "New Zealand Science in World War II", Unpublished report, Auckland Public Library, ref.no. NZ/MSS/804, p. 3.27.
10. Smith, R. A., R. Hanbury-Brown, A. J. Mould, A. G. Ward and B. A. Walker, 1985. *Proc IEE*, **132A**, p. 359.
11. Burbidge, P. W., 1952. ibid, p. 3.42.
12. Rowe, A. P., 1948. "One Story of Radar", University Press, Cambridge, p. 64.
13. Burbidge, P.W., 1952. ibid, p. 3.63.
14. Price, A., 1984. ibid, pp.136-137.
15. Atkinson, J. D., 1976. "DSIR's First Fifty Years", Wright & Carman, Wellington, p. 48.
16. Taylor, N. H., 1969. In "Sir Ernest Marsden, 80th Birthday Book", A. H. and A. W. Reed, Wellington, p. 84.

NOTE BY EDITOR

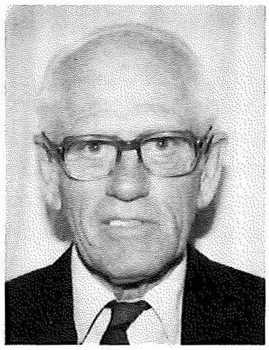
The developement of defence radar in NZ before and during WW II owes much to Ernest Marsden. The following was gleaned from his "80th Birthday Book"(16) which Bob Unwin lent me.

Like NZ's greatest physicist, Lord Rutherford, he was another Ernest, though he was a Briton who spent most of his life in NZ, while Rutherford was the other way round. His work in Rutherford's Laboratory with Hans Geiger in 1909 which lead to the discovery of the atomic nucleus, was done when he was only 20. Largely as a result of this he was appointed Professor of Physics at Victoria University College, Wellington, NZ, in 1914, when he was still only 25.

He took up this position in 1915 but joined the NZ Forces, serving with the rank of Lieutenant, later Major, with the NZ Divisional Signals Co. in France. Meanwhile, his friend and collaborator, Hans Geiger, was caught up on the other side. A quirk of fate found them fighting on opposite sides of the trenches in the same sector of the front in France. There Marsden received a letter from Geiger, forwarded through Neils Bohr in Denmark, congratulating him on his appointment to the Chair in Wellington which he returned to in 1919.

ABOUT THE AUTHOR

Robert ("Bob") S. Unwin is well known to many URSI people for his pioneer work in auroral radar. After graduating from the Canterbury College of the University of New Zealand in 1940, he worked in the New Zealand Post Office and Scientific and Industrial Research Department on radar development and operations in New Zealand and the Pacific, including two years in radar and radio countermeasures in the South and South-West Pacific theatres of war. In 1946/47 he headed a joint NZ/UK investigation on meteorological effects on radio wave propagation, and continued research in this field both in New Zealand and the U.K. until the mid-fifties. From mid 1957 he headed a DSIR and university team established at Invercargill in the south of the country for studies of the aurora australis and related phenomena during the International Geophysical Year. His research interest remained in this field (particularly auroral radar) through the remainder of his career in DSIR, first at Invercargill then at the PEL Auroral Station* which he set up at Lauder in the South Island, and from 1971 as superintendent of the Geophysical Observatory in Christchurch. He was awarded a D.Sc. by the University of Canterbury in 1982, and now lives in retirement at Wanaka.



* Now the DSIR Physical Sciences Atmospheric Station.

4th International Seminar on Mathematical Methods in Electromagnetic Theory (MMET'91)

Crimea, September 18-23, 1991

It was certainly the most unusual conference I ever attended. The organizers went ahead with it in spite of all the economic and political disruptions occurring in the Soviet Union in the summer of 1991. Twice the dates of the conference had to be altered because the hotel rooms became unavailable. Yet the difficulties which befell the organizers seemed to simply add to the camaraderie which developed among the affected participants. The relatively small number of people involved (85) made innovation possible and the specialized nature of the meeting contributed to its effectiveness.

Eldar Veliev and Alexander Nosich of the Institute of Radiophysics and Electronics, Ukrainian Academy of Sciences in Kharkov were co-chairmen and organizers of the meeting. It was also co-sponsored by "Test Radio", a Kharkov research and development firm headed by Valery Zhilkov. The first two meetings of this series of seminars had only Soviet participants. The third, in April 1990 had four invited foreign lecturers and adopted English as the working language. At this 1991 meeting there were invited speakers from Australia, Canada, Japan (5), Korea, Sweden, Turkey (5) and USA. It was held in the attractive Black Sea resort city of Alushta.

For most of the foreign guests the seminar was preceded by a tour on overnight trains from Moscow to Simferopol with a stopover at a hotel in Kharkov. This bonus trip, all expenses paid by the organizers, occurred because the hotel Yunost in Alushta had no rooms for us. In Kharkov we visited the Institute of Radiophysics and Electronics and were received by its director V. P. Shestopalov, who is well known for his work on diffraction gratings. We were shown some of the remarkable technical achievements of the institute in active and passive millimetre wave devices, remote sensing instruments and polarimetric radars. Diffraction grating specialists in the group were particularly impressed by their use in powerful diffraction radiation generators.

After this unexpected tour in the Ukraine the conference began in Alushta. The six day programme of 66 papers, including 28 one hour lectures, 18 twenty minute presentations and 20 poster papers all occurred in one room. There was plenty of open commentary, criticism and discussion. This can be the most interesting part of a meeting and too often there is not enough time for it at our large meetings in the west. The traditional strong background in applied mathematics, evident in the Ukrainian and Russian presentations, ensured that numerical solutions did not dominate. What has changed since my last conference in the Soviet Union (1971) is the ability of our Ukrainian and Russian colleagues to communicate well in English. It is now far easier to follow their talks.

Midway through the conference there was an excursion to Yalta and the palace where the 1945 agreement which divided Europe for the next 45 years, was signed. The banquet that evening included lively Ukrainian dancing with participation apparently expected of all visiting foreigners.

Unfortunately because of the altered dates I had to leave before the end of the conference. So I missed some of the papers and the final excursion, but I heard about it. It was a hike to an unusual spot — a hilltop overlooking the Black Sea villa where Premier Gorbachev was on involuntary "sick leave" only a few weeks earlier. Then it could have been a dangerous place to be. Hearing of this reminded me of the remarkable fax message we got from Alex Nosich, the organizer, about 4 weeks earlier. It was sent August 20 and urged us not to cancel our plans to attend MMET'91 because of the temporary disturbances in Moscow. It said he was certain the coup was abortive and that normal conditions would prevail by the time of our meeting. Fortunately he was correct.

The organisers and sponsor are to be congratulated for a successful and enjoyable meeting. Copies of the 410 page proceedings can be ordered from:

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E. V. Jull

CONFERENCE REPORT

Wave-induced Particle Precipitation

This session was held on 17 August 1991 during the 20th IUGG General Assembly in Vienna by the URSI/IAGA Joint Working Group on *VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere* (VERSIM). It was well attended by up to 25-35 scientists, and 17 papers (including posters) were presented on a variety of topics including satellite observations of waves and particles, ground based observations and theoretical modeling work. Highlights of some of the talks are summarized below: **Paranicas** *et al.*, reported the observations on the CRRES satellite of electrostatic n+1/2-type emissions which exhibited banded structure, possibly associated with structure in the plasma (30 eV to 40 keV electrons). **Vampola** *et al.* presented electron spectrometer data from the CRRES satellite obtained during chemical releases. Increases in 100—600 keV electron fluxes were observed when the satellite was in the diamagnetic cavity. **Schriver** *et al.* presented results of computer simulations of artificial aurora that would be induced by the precipitation of energetic electrons by intense whistler waves that build up in the dense lithium plasma cloud in CRRES experiments. Calculations indicate that fluxes at the levels of diffuse aurora can be produced. There are as yet no experimental results. **Cornilleau-Wehrlin** *et al.* presented results of the analysis of extensive wave/particle data from the GEOS-1 satellite during quiet times when the spacecraft was within the plasmasphere. In 48 different cases observed, the strongest hiss (0.1—3kHz) intensities corresponded to the largest fluxes of 15-300 keV electrons, and the flux levels in all cases were found to be sufficiently high to produce growth of hiss waves to observed levels in a single pass through the geomagnetic equator. **Hayakawa** *et al.* reported results of broadband VLF measurements of whistlers and whistler triggered emissions at Ceduna, Australia (L=1.93), with many events (especially triggered hiss) being observed. **Inan** gave a review of recent subionospheric VLF measurements of lightning-induced electron precipitation effects. The location of disturbed ionospheric regions are clearly identified by means of multiple point measurements on collinear VLF paths, and information on the altitude profiles of disturbed regions (and hence the energy spectrum of precipitated electrons) can be deduced by means of selective perturbation of high order waveguide modes on short (<1000 km) VLF paths. **Poulsen** *et al.* presented a new 3-D model of subionospheric VLF propagation in the presence of localized ionospheric disturbances. The model is general and takes into account the altitude profile of ionization in disturbed regions (rather than treating the disturbances as merely a reflection height change). Results indicate that amplitude and phase changes at receivers on typical Great Circle Paths are highly sensitive to the details of the altitude profile. **Dowden** *et al.* presented results of VLF observations on a 1200km array of five stations across New Zealand. Coherent observations of signals from the NWC transmitter allow the localization and 'imaging' of lightning-induced ionization enhancements (LIEs). In different cases disturbances were deduced to have dimensions of ~ 100 km or smaller (tens of km). **Smith** *et al.* described statistical results on more than 2000 trimpi events from a whole year (1989) of operation of OPAL-type receivers at Faraday and Halley, Antarctica. By comparison with models, it was possible to deduce the typical location ($2 \leq L \leq 3$) and size ~ 50-100km in latitude and ~ 200-500km in longitude). **Friedel** and **Hughes** presented results of test particle simulations of gyroresonant scattering of electrons at low L-values (L<2), showing that very large (100 nT) wave amplitudes are needed to explain observed events unless the wave-particle interaction region is temporarily lengthened by geomagnetic field changes (e.g. Pc5 pulsations). **Burgess** and **Inan** showed new evidence of disturbance of conjugate ionospheres in individual lightning events. Direction-finding analysis on whistlers observed at Palmer Station, Antarctica indicate that most trimpi events observed at Palmer may be caused by ducted whistlers. **Fennell** *et al.* presented results of a comprehensive statistical analysis of data from the SCATHA satellite, which indicates that Electron Cyclotron Harmonic (ECH) wave intensities are too weak to explain the observed diffuse auroral fluxes. In most cases the electrons are found to be not in strong diffusion. **Kozyra** *et al.* described results of theoretical analysis of anomalous Doppler shifted cyclotron resonance interaction between protons and ducted plasmaspheric hiss. Computed lifetimes for scattering of protons into the loss cone are consistent with ring current decay. **Friedel** and **Hughes** reported observations of low latitude trimpi events at Durban (L=1.7) using an OMSKI receiver on paths to the north (GCPs from NAA, Omega Reunion, etc.); most occurred in a two hour interval when there were thunderstorms over South Africa. **Singh** *et al.* discussed the relationship between ionospheric irregularities over India derived from high frequency scintillation measurements, and whistler ducts inferred from observations of low latitude whistlers at Varanasi.

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(from VERSIM)

Diffraction by Mountains

Prompted by a paper by *Syed and Volakis* [1991] I wish to identify some misprints in an early paper by *Wait and Conda* [1959] that is quoted often in the recent literature — sometimes out of context. In eqn. (5), the two g functions have arguments $[(\frac{\pi}{2} \pm \phi' + 2\pi m)(ka/3)^{1/3}]$

Note also that, in (9b) and 9(c), x_1 and x_2 are defined by $x_1 = (ka/2)^{1/3}[(\pi/2) + \phi']$ and $x_2 = (ka/3)^{1/3}[(\pi/2) - \phi]$

Finally in eqn. (10a), replace ϕ by $(2\pi m + \phi)$ and in eqn. (10b), replace ϕ by $(-2\pi m + \phi)$.

As is clear from the title of the paper in question, the final results are only intended to be used for small grazing angles of incidence when both the transmitter and receiver antennas are at a large distance from the diffracting crest. This fact is also evident from the analytical discussion in this 1959 paper.

Extensions and generalizations of the *Wait and Conda* [1959] paper clarify some of the limitations of the earlier work that readers may not be aware of. For example see *Wait* [1967] and *Vogler* [1985].

References

Wait, J. R. and A. M. Conda, Diffraction of electromagnetic waves by smooth obstacles for grazing angles, *J. Res. Natl. Bur. Stand.*, *63*, Ser.D, 181-197, 1959.

Wait, J. R., Theory of diffraction by a curved inhomogeneous body, *J. Math. Phys. 8*, 920-925, 1967.

Vogler, L. E., Radio-wave diffraction by a rounded obstacle, *Radio Science*, *20*, 582-590, 1985.

Syed, S. H. and J. L. Volakis, High frequency scattering by a smooth coated cylinder simulated with generalized impedance boundary conditions, *Radio Science*, *26*, 1305-1314, 1991.

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RESEARCH LETTER

Real ray-tracing in a dissipative medium — Possible?

In order to describe the motion of wave packets as these propagate over large distances, first-order differential equations have been developed, the so-called ray-tracing equations. Fundamentally they contain the group velocity $d\omega/dk$, where $\omega(k)$ represents the dispersion relation of the medium. The equations, which different authors have derived in different ways, are well established and indisputable — at least for a medium free of dissipation.

When the medium is dissipative, which is most often the case, the dispersion relation becomes complex, so that $d\omega/dk$ is complex. As a result, any ray becomes complex even if it were initially real. One faces then a dilemma. Either one accepts the complex group velocity and tries to interpret the resulting complex space coordinates, or one searches for another expression which would yield real group velocities even where there is dissipation. Some authors have developed techniques based on complex rays, which they applied to radio-wave propagation in the ionosphere (e.g. [1]).

In principle, all the information regarding the evolution of a wave packet is contained in a Fourier integral

$$\Phi(x,t) = \int \frac{dk}{2\pi}\chi(k)\exp i(kx - \omega(k)t),$$

where $\chi(k)$ represents the packet in Fourier space at time $t = 0$. If one supposes that this initial packet is localized in coordinate space about $\bar{x}$ and has in Fourier space a width Δ around the central wave number $\bar{k}$ it can be shown, using a saddle-point method, that the subsequent positions of the packet centres in coordinate space, $x_M(t)$, and in Fourier space, $k_M(t)$, are related. The relation reads

$$(x_M - \bar{x}) + i\left(\frac{k_M - \bar{k}}{\Delta^2}\right) = \frac{d\omega}{dk}\Big|_{k_M} t\,.$$

Since the expression is complex, we have some freedom in the way we split it into its real and imaginary parts. There are two reasonable choices.

1) One may argue that, given the homogeneity of the medium, the central wave number should remain constant, i.e. $k_M = \bar{k}$. Unavoidably then, one has to allow for $(x_M - \bar{x})$ (or possibly t) to be complex. This is the conventional choice for defining a ray, for example the one of *Connor and Felsen* [2]. The initial conditions given on the x-axis are analytically continued into a complex plane. One may visualize it as perpendicular to the real (x,t) plane along the $t = 0$ line. Then, a complex ray intersecting the real world at the point of interest (x,t) is used to convey the initial/boundary information from the initial complex plane to the point considered. An evaluation of the total field there requires one finally to synthesize the contributions from a family of complex rays.

2) One may argue that the ray represents physically the trajectory of the wave packet in coordinate space and, therefore, has to stay real. The price to pay in this case is to let the wave number k_M drift away from its initial value $\bar{k}$ as in usual WKB where there are spatial gradients. The equation above splits into

$$x_M = \bar{x} + Re\left(\frac{d\omega}{dk}\Big|_{k_M}\right) t$$

$$k_M = \bar{k} + \Delta^2\, Im\left(\frac{d\omega}{dk}\Big|_{k_M}\right) t\,.$$

Let us consider for example a dispersion relation of the type

$$\omega = \frac{\alpha}{2}k^2 - i\frac{\beta}{2}k^2$$

with $\beta > 0$. This could represent whistler waves in a collisional plasma. We obtain $k_M(t) = \bar{k}(1 + \beta\Delta^2 t))^{-1}$ and $x_M = \alpha k_M t(1 + \beta\Delta^2 t)^{-1}$. Thus, the central wave number decreases slowly from its initial value $\bar{k}$, and the propagation speed diminishes accordingly:

$$dx_M/dt = \alpha k_M(1 + \beta\Delta^2 t)^{-2}.$$

The second viewpoint has been recently investigated in detail [3]. It was shown that in a moving frame attached to $x_M(t)$ the wave packet looks self-similar. A Gaussian packet remains Gaussian, as is familiar in a non-dissipative medium. Further, its height can be computed self-consistently in terms of integrated damping (or growth). These two features substantiate the second viewpoint significantly: the ray *is* the trajectory of the wave packet in physical space. A set of 'ray-tracing' equations has been proposed to follow the packet centres in coordinate and Fourier spaces. Until now, the set has been derived for the case of a homogeneous medium. Yet, *a priori* the formalism may be extended to the inhomogeneous case, allowing one to do real ray-tracing. The important point is that one can keep the trajectory of the packet in coordinate space *real*, provided that the wave number is allowed to vary adequately.

[1] Bennett, Proc. *IEEE, 62,* 1577 (1974).
[2] Connor and Felsen, *Proc. IEEE, 62,* 1586 (1974).
[3] Muschietti and Dum, (submitted *Phys. Fluids,* 1991).

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Low Angle Microwave Propagation: physics and modelling

Adolf J. Giger
261 pages, Artech House, Boston, 1991
ISBN 0-89006-584-5

This monograph is one of the titles from the Artech House Tele-communication Library. Like many of the books published from Artech, it deals with practical engineering design. In the present case, the author has benefited from an extensive career in telecommunication and system planning. Thus it is evident that the material will be eminently useful. In the Foreword written by a director at the AT&T Bell Laboratories, it is stated that Giger "presents for the first time a propagation model which is derived entirely from physical phenomena and thus couples the characteristics of a propagation link to the performance of digital transmission".

In the first part of the book, the author deals with some basic propagation physics. He seems to follow closely previous publications of Bell Lab. authors even though they are not always explicitly noted. But most of the fundamental theory comes from the early work of D. E. Kerr of MIT Rad Lab fame ("Propagation of Short Radio Waves", 1951 now available from Peter Peregrinus, Stevenage UK). Giger does show some new insight and his illustrations are nicely done. Too bad he seems to be mixed up a bit on his time factor. On page 22 he indicates it is exp(-jωt) whereas his equations use exp(+jωt). He gives the reader a nice discussion of the relationships between ray and mode theory but no mention is made of non uniform tropospheric ducts which are common in the real world. This reader is perplexed why no coverage is given to the effects of atmospheric turbulence except possibly for his discussion of the observed rapid fading. Surely the "physics" of the propagation should touch on this subject. A curious omission is a reference to the monograph *Radar Propagation at Low Altitudes* by M. L. Meeks, (Artech House, 1984) where many related references are listed.

James R. Wait

Non-conventional methods in Geoelectric Prospecting

Mark M. Goldman
153 pages. Ellis Horwood/Prentice Hall, 1990 ISBN 0-13-626813-7

This slim monograph could have been a two part paper in a regular journal. It really is an incisive account of the author's personal investigations of analytical and numerical techniques to deal with the electromagnetic response of horizontally layered structures. The results are cast in the context of geophysical sub-surface probing employing both time-harmonic and transient fields. A great deal of attention is paid to the errors that can rise in poorly convergent integral representations of the fields of electric and magnetic dipole sources. Some of the existing off-the-shelf computer programs are evaluated in a critical fashion and significant errors are found and documented in a thorough fashion. Caveat emptor!

The book seems to have been very carefully assembled and written. However, I found a few minor inconsistencies in the notation that might be a source of confusion to some readers. For example the complex propagation constant k on page. 16 seems to have a phase angle of +45° whereas it should be -45°. Then on page. 26, the k seems to be defined differently where in fact it would make the Sommerfeld integral blow up as distance R goes to infinity. Also dielectric effects are ignored without any real justification given. Note that, in the real earth, effective permittivities relative to free space can be as high as 10,000 for frequencies in the audio range and they are highly dispersive.

The $105 advertised price of the book will put it out of the range of most individuals and I know of at least one university library that will balk at such an expenditure.

James R. Wait

BOOK REVIEW

Electromagnetic Methods in Applied Geophysics, Vol. 2, Parts A and B – Applications

Misac N. Nabighian (Ed.)
971 pages. Society of Exploration Geophysicists, Tulsa OK 74710-2740, 1991.
ISBN 1-56080-22-4
Price $200 (approx.).

This two part collection of outstanding articles is a sequel to Vol. 1 published in 1988 (see review in the IEEE/AP-S *Magazine*, p. 20, 1988). The emphasis is now on application of electromagnetic sounding techniques to probe the subsurface layers of the earth's crust. The motivation with all this work has been the search for commercial minerals prior to actual mining these resources. But this is probably a rather narrow perspective of this impressive contribution. The authors, selected by the eminent editor, are all prime movers in the field. The individual chapters cover specific methods and they are usually accompanied with enough background theory to stand alone. The overlap with Volume 1 is not undesirable and, in fact, it is helpful for the reader to refer back to the basic and rigorous derivations and fundamental concepts, found in Volume 1, for a deeper understanding.

A common feature of the methods is that the significant distances, such as exploration depth and separation between source and observer, are small compared with the free-space wavelength. On the other hand, these distances are comparable with the electrical skin depth. In fact it might be said that the key element, of many of the schemes being described, is to exploit the fact that the frequency dependence of the electromagnetic induction response is a rich source of information. Comparable schemes working in the time domain are possibly even more attractive in this regard.

As in Volume 1, the uniformity of the coverage, from one chapter to the next, is remarkable. Each author has a story to tell and it is so refreshing to see how smoothly flowing is the prose. I suspect the editor gives a big assist here. Both Parts A and B are lavishly illustrated including colour plates. I suppose this is a partial excuse for the high price.

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THE EDITORS PAGE (continued from page 3)

doing most of the work here at no cost to URSI, the total cost to URSI is low. In fact, paid advertisements amounting to only a few of the 28 pages per issue would cover the printing costs.

I would like to stress that editing *the Radioscientist* is an enjoyable and rewarding job, because I would like to hand it over to some one else at the end of next year. Interested?

Game show

I found this intriguing puzzle in Rajeev Bansal's "AP-S Turnstile" section in the October, 1991 issue of the IEEE AP-S *Magazine*. It previously appeared in the June issue of the same Magazine and "originally" in *Parade Magazine* (9 September, 1990), but some people have known it long before that. So I'll present it here to you in a different way (I changed "goats" in the original to "toys").

You must be familiar with TV game shows where the contestant who wins the quiz part of the game can choose between a money prize and an unknown prize which could be worth far more or could be worth nothing. Our hypothetical game show is different in that the contestant gets to choose one of three doors, behind which one has a car and behind the other two are worthless toys. When the contestant announces his choice the game show host, who knows what is behind each door, opens one of the other doors to show a toy behind it and tells the contestant he can, if he wishes, change his choice. This is not unexpected for the contestant because the show is *always* run like this to heighten the fun for the TV audience. The question is, *should the contestant change from his first choice?*

One might argue that there is no information to gained from the offer of the second choice since it is made regardless of whether the first choice was correct (would win the car) or not. Therefore there is an equal chance of the two unopened doors being the correct one.

Another might argue that the probability of the first choice being correct stays 1 in 3, so the probability of the second unopened door being correct must jump to 2 in 3. So therefore he should change his choice to double his chances!

Neither of these arguments is adequate but one comes to the right conclusion. For my argument and conclusion, see the box on the back page.

Editor's address

For the six months 1 May to 1 November, 1992, I will be visiting MPAe at Lindau, Germany. This temporary address is given on the top left corner of page two. Please submit contributions (by email, fax or letter) to there. Subscriptions, however, should still be sent to Dunedin.

The Radiation Laboratory — Fifty Years Later

The 50th anniversary of the Radiation Laboratory of MIT was celebrated at the 1991 IEEE Microwave Theory and Techniques Society Symposium (MTT-S) in Boston, June 10-14, 1991. The keynote speaker at the opening Plenary Session of MTT-S, on Tuesday morning, June 11, was Dr. Norman Ramsey, winner of the 1989 Nobel Prize in physics and Radiation Laboratory alumnus, who spoke on "Some Implications of Radiation Laboratory Developments." I will give my impressions of the celebration, the Radiation Laboratory (the "Rad Lab") as it existed from 1940 to 1945 (Figure 1), and of relationships of developments at the Rad Lab to present activity in radio wave propagation and remote sensing. I was at the Rad Lab from June, 1942, to October, 1945.

Following the Plenary Session of MTT-S, Session C consisted of presentations by Nathan Marcuvitz on "Microwave Theory," Robert Pound on "Microwave Components," and Ivan Getting on "Microwave Systems." Also, Robert Dicke, the inventor of the radiometer, gave "Brief Remarks" in Session L, on Microwave Radiometers. Professor Dicke received the Pioneer Award at the MTT-S Banquet. In addition, Britt Chance presented a paper in Session BB on "Time and Frequency Technology for Studies of Functioning and Malfunctioning Muscle and Brain." All of the authors mentioned were prominent at the Rad Lab during my period there.

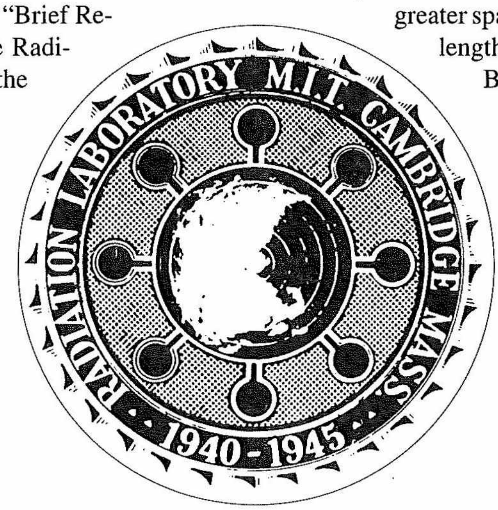

Figure 1. The Radiation Laboratory seal, showing magnetron cavities and a radar image, including Cape Cod, in the center.

On Tuesday, from 5 to 8 pm, a reception was held for Rad Lab alumni and friends near the Symposium Historical Exhibits Area. This provided an especially good opportunity for Rad Lab alumni to renew acquaintances, or to meet Rad Lab people they did not know at the Rad Lab itself. The Rad Lab employed about 3,900 people at its peak, in August, 1945, and about 1,200 were technical Staff Members. At least 6,446 people spent at least some time at the Rad Lab, by the time of its final termination, on December 31, 1945. Many of us walked around looking at names on badges, as these were often more familiar than faces, after close to 50 years. Many of us left the reception early, to arrive in time for the 8 pm Boston Pops concert in nearby Symphony Hall, where Rad Lab people sat together.

The Symposium Banquet was held at the Westin Hotel. Hearing that Daniel Schorr was to be the speaker influenced me favourably to attend. Rad Lab people sat together at tables reserved for them. Thanks are due to Ted Saad, fellow Rad Lab alumnus, for his initiative and energy in arranging for the Rad Lab celebration, and to MTT-S, for its wholehearted cooperation and support in all respects.

The Radiation Laboratory, 1940-1945

In 1940, when the German armed forces had overrun much of Europe, concern developed about the need for collaboration between scientists and the armed forces in the United States. Dr. Vannever Bush, Dean of Engineering at MIT and scientific adviser to President Roosevelt, put ideas developed by himself, Dr. James Conant, the President of Harvard University, and Dr. Karl Compton, the President of MIT, on a sheet of paper, spent 15 minutes with President Roosevelt in early June, 1940, and left with "OK FDR" for forming a National Defense Research Council (NDRC). A Microwave Committee, chaired by Alfred Loomis, was soon established as part of the NDRC. A problem in 1940 was that there was no transmitting tube known in the United States that could supply enough power at a wavelength like 10 cm. A wavelength of this order or smaller was needed to obtain greater spatial resolution than the longer-wavelength radars used up to that time. The British, however, came to the United States in September, 1940, on the Top-Secret Tizard mission, with a surprise: a resonant-cavity magnetron, suitable as a source of microwave power. Following extensive discussion and attention to strategy, it was decided to establish a laboratory, along British lines, at MIT. Dr. Lee DuBridge, of the University of Rochester, was appointed as its Director. The laboratory, by then known as the Radiation Laboratory, was ready for business by November, 1940. The choice of the name Radiation Laboratory, together with the appointment of Lee DuBridge, a nuclear physicist, as Director, tended to divert attention away from the true function of the laboratory. On January 4, 1941, radar echoes were first received at MIT, by a 10-cm radar, from buildings across the Charles River. On February 7, 1941, echoes were first received from an aircraft flying over Boston airport, at a range of four to five miles.

The British Tizard mission, headed by Sir Henry Tizard, came to the United States and Canada with the intentions of handing over to the United States information about all the recent British technical advances, and of enlisting the cooperation of the United States in a program of research and development. E. G. "Taffy" Bowen was the member of the

Tizard commission with responsibility for radar. A fascinating account of the Tizard mission, and of the formation of the Radiation Laboratory, written by E. G. Bowen and excerpted from his *Radar Days* is included in *Five Years At the Radiation Laboratory, 1991 IEEE MTT-S International Microwave Symposium Edition* [1]. *Five Years* is an excellent general reference on the Radiation Laboratory, and I have made considerable use of it in writing this article. Other good references, distributed at MTT-S, are the special issue of the *IEEE Aerospace and Electronic Systems Magazine*, devoted to the Rad Lab (October, 1990), and the Spring, 1991, issue of *RLE currents*, a publication of the Research Laboratory of Electronics at MIT.

The Rad Lab was organized into the Office of the Director and twelve divisions, to which I will give only brief and uneven attention. Division- and Group-leader assignments changed from time to time, and I will often not give complete information about them. Divisions 1, 2, and 3 were administrative in nature, and were designated as the Business Office, Buildings and Maintenance, and Personnel and Shops, respectively. Division 4, headed by I. I. Rabi, was devoted to research, including advanced research programs. It included Group 42, which dealt with Propagation. This group was headed by Donald Kerr, from June, 1942, to February, 1945, and from September, 1945, to December, 1945. Donald Kerr is well known as the Editor and an author of Volume 13 of the Radiation Laboratory Series of 28 volumes, *Propagation of Short Radio Waves* [2]. Division 5 was a large division that dealt with Transmitter Components, and was headed by Jerrold Zacharias from January, 1944, to July, 1945. Alfred Hill took over after that. Group 51 worked with Modulators, and Group 52, headed by George Collins from June, 1941, to June, 1945, was designated as the Transmitters Group, but it was probably more commonly thought of as the Magnetron Group. It could well be considered to have been the heart of microwave development. Group 53 dealt with RF, more descriptively, "RF plumbing," and it was also referred to as the Microwave Group. Group 54 was the large Antenna Group, headed by Lester Van Atta from September, 1945, to December, 1945. Sam Silver, of this group, wrote Volume 12 of the Rad Lab Series, *Microwave Antenna Theory and Design* [3].

Division 6 was another large division, and was concerned with Receiver Components. Leland Haworth headed the division, after Robert Bacher and Louis Turner. Stanley Van Voorhis was the head of Group 61, Receivers, and Chalmers Sherwin and John Sollers were Leaders and Associate Leaders of Group 62, Indicators, at different times. Britt Chance was the head of Group 63, which dealt with Precision and Indicator Components. Division 7 dealt with Beacons, and Division 8, headed by Ivan Getting, dealt with Fire Control and Army Ground Forces. Division 8 was responsible for the versatile and well-travelled SCR-584 X-band radar [4]. Division 9 worked with Airborne Systems. Milton White followed Louis Ridenour as head of Division 9. It is generally believed that the ASG radar, developed by Division 9, did more to defeat the submarine menace than any other microwave set.

Division 10 was the Ground and Ship Division, and was headed by J. C. Street, who followed Ernest Pollard and Ray Herb. Group 101 dealt with Mechanical Engineering, with Michael Karelitz as the leader. I give special attention to Division 10 and to Group 102, Ship Applications, because these were the division and group in which I served. Divisions 8, 9, and 10 were systems divisions, and were concerned with the operation of complete systems, as contrasted with the research on, and development of, system components. As members of system divisions, we had frequent occasion to consult with members of divisions like Division 5 (Transmitter Components) and Division 6 (Receiver Components). Also, in many cases, we followed through with systems to the production stage. I had a badge to admit me to the Raytheon Company, for example. John Hall and Ralph Meagher were leaders of Group 102. I worked most extensively with Ralph Meagher, Niels Edlefsen of the division office, and Dick Blue. System-wise, I was involved with the SO and SQ shipboard radars, and with the VF indicator for shipboard use. As a division concerned with the overall operation of ship systems, Division 10 had an interest in propagation, and had an Over Water Tests program. In May and June, 1944, I spent some time at the Fishers Island, New York, field site of the Rad Lab. An over-water link operated between Fishers Island and the mainland. Arthur Vane, of Group 42, Propagation, and I, met at the 50th reunion, and recalled that we had first met each other at Fishers Island.

In addition to working with Group 102, I was detailed to Project Cadillac, from August, 1944, to October, 1945. This, the most ambitious program ever undertaken by the Rad Lab, was sponsored by the Navy. Project Cadillac involved radars in aircraft which transmitted signals to aircraft carriers. For my first flight in an aeroplane, I flew from Boston to San Diego in a DC3, in March, 1945. The trip took about 22 hours. There, I participated in the first installation of Project Cadillac on the carrier Ranger, operating out of San Diego, and I went out to sea on the Ranger when it went out, with pilots on board, for training in carrier takeoffs and landings. Later, I was at Bremerton, Washington, for an installation on the Enterprise.

Division 11 was the Loran Division, and it was concerned with Navigation. It operated separately from the radar divisions. Loran can be regarded as a forerunner of modern precision-positioning systems using GPS satellites. The Field Service Division, Division 12, worked in close cooperation with the Army and Navy, at home and abroad. A major field station was the British Branch of the Radiation Laboratory (BBRL). One group of men went to Italy, to help with the needs of the 15th Air Force, and Rad Lab field service was also carried out in the Pacific theatres.

Concluding Comments

The Radiation Laboratory was very well managed, and it was an exciting place to work. Dr. Lee A. DuBridge was the Director, Dr. Francis W. Loomis was Associate Director for Personnel and Shops, and Dr. I. I. Rabi was Associate Director for Advanced Research, and also head of Division 4, Research. Francis W. Loomis and Albert L. Loomis should not be confused. Albert Loomis was the head of the Microwave Committee of the National Defense Research Council (NDRC), and played an important role in establishing the Radiation Laboratory. He later was the Chairman of the Radar Division of the Office of Scientific Research and Development (OSRD), and he had what was called a courtesy appointment at the Rad Lab. In addition to the specific tasks to which Rad Lab Staff Members were assigned, I remember meetings or convocations where we heard presentations about scientific matters, the progress of the war, and how various Rad Lab programs were proceeding. I believe that these convocations took place on Tuesday evenings. I arrived at the Rad Lab at the age of 21, after receiving a BS in Electrical Engineering from the University of Washington, and travelling by train from Seattle to Boston.

As pointed out in the article about the Rad Lab in the *Proceedings of the IEEE* (March, 1991 [5]), physicists played the leading role at the Rad Lab. After the decision had been made to form the Rad Lab, a number of the well-known physicists of the time were called to the Lab for consultation and possible employment. Recruiting of physicists and engineers, with emphasis on recruiting from universities, then proceeded further, and Dr. Ernest Lawrence, of cyclotron fame, turned his energy to the task. Also, Dr. L. C. Marshall, of the University of California, Berkeley, came to the University of Washington, in the spring of 1942, for recruiting purposes. Graduating seniors were invited to attend a meeting, at which Dr. Marshall was to speak about work at the Rad Lab. I had already been turned down for a commission in the Navy, because of being too near-sighted, and I signed up with Dr. Marshall on the spot for work at the Rad Lab.

Five Years devoted some attention to activities of Rad Lab people away from the Lab as well as to Lab work, and I will mention that I was a very active birder and member of the Massachusetts Audubon Society while at the Rad Lab. We worked at the lab until noon on Saturday, for a good part of my stay at the lab, but my Sundays were commonly devoted to travelling somewhere by train for birding. A favourite location was Newburyport and nearby Plum Island, and I decided, after the reunion at Boston this year, that I would renew my acquaintance with Plum Island, for the first time since leaving the Rad Lab in October, 1945.

Dr. Lee DuBridge was an excellent Director for the Rad Lab. He was a highly-respected Professor of Physics, from the University of Rochester, and a most pleasant as well as competent person. He presided over meetings efficiently and with assurance, always kept a cool head, and never seemed to express anger. DuBridge sent a very fine letter of greetings to the 50th reunion of the Rad Lab, but could not attend for reasons of his health.

Nine persons who worked at the Radiation Laboratory have received Nobel Prizes. All but two prizes were in physics. Those receiving prizes in physics were Isaac Rabi, 1944; Edward Purcell, 1952; Julian Schwinger, 1965; Hans Bethe, 1967; Luis Alvarez, 1968; Jack Steinberger, 1988; and Norman Ramsey, 1989. Edward McMillan received a Nobel Prize in chemistry in 1951, and Paul Samuelson received a Nobel Prize in Economics in 1970. The case of Dr. Samuelson is interesting. He received a PhD from Harvard, in 1941, in Economics and Statistics. Very likely, his training in statistics was helpful to his work on fire-control problems at the Rad Lab.

The years that I spent at the Rad Lab have always been cherished, but they had come to seem very distant. The 50th reunion brought the Rad Lab years vividly back to consciousness. I was sorry not to see a number of the people at the reunion that I knew at the Rad Lab. Some were not on the list of persons who said that they would or would not attend, and there was often no way to know if a particular person, not on the list, just did not hear of the reunion, or did not contact Ted Saad or MIT about it, or had passed away.

References

[1] *Five Years At the Radiation Laboratory, 1991 IEEE MTT-S International Microwave Symposium Edition*, Massachusetts Institute of Technology, Cambridge, Massachusetts.

[2] Cherry, D. D. (Ed.), *Propagation of Short Radio Waves*, New York, McGraw-Hill, 1951.

[3] Silver, S. (Ed.), *Microwave Antenna Theory and Design*, New York, McGraw-Hill, 1949.

[4] Getting, I. A., "SCR-584 radar and the Mark 56 naval gunfire control system," *IEEE Aerospace and Electronics Systems Magazine*, **5**, pp. 3-15, October, 1990.

[5] Brittain, J. E., "Scanning the Past, The Rad Lab at Fifty," *Proc. IEEE*, **79**, p. 92, January, 1991.

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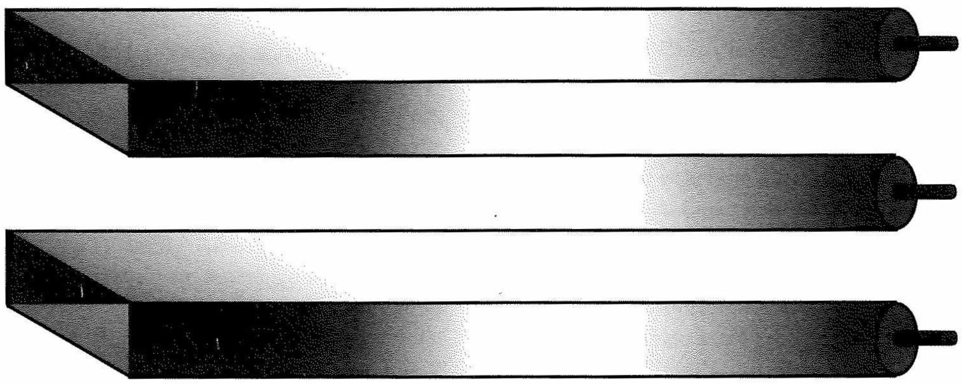

Microwave phantom circuit!

As is well known, a two pair telephone line (e.g., a quad) can carry three wide band signals simultaneously — one in each of the "physical" pairs and a third in the "phantom" line consisting of the pair of pairs. Recent research, drawing heavily on the work of M. C. Escher, has now extended this to the microwave region. The above figure shows the *Escher Link* for coupling the three coaxial signals into the two waveguides, A and B. An identical *Escher Link* is used to couple the signals out at the receiving end.

Although the signals in the waveguides can be express in complex form in the usual way, a curious feature of the *Escher Link* is that only the imaginary components are non-zero. The phantom signal exhibits tachyon behaviour — the phase velocity is less that the speed of light but the group velocity is greater. This suggests near infinite signal speeds at near the cutoff frequency.

[Ed. I regret that this note has not been refereed and that the author refuses to reveal his/her name].

My game show solution

If the show repeats every night for many years, then in one case in three the door the contestant chooses first has a car behind it (we must assume that cheating such as switching car and toys after his first choice is not allowed). When this is the case both the other doors have toys behind them so the host can open either to show a toy.

But in two cases out of three the door first chosen has a toy behind it. In each of these two cases there is only one door for the host to open to show a toy, so the only remaining door (unopened and not that chosen first) has the car behind it. Thus the contestant has twice the chance of winning the car if he changes his mind (I say "he" because a woman would have known this intuitively).

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