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NOTES ON THE A510

Personal Recollections by K.G. Dean

The Wireless Station A510 was a unique set in so many ways that it is worthwhile noting its background - that is the background as I recall it.

Before the Second World War, all frequencies above the short-wave band were still often loosely called UHF. Whereas the higher frequencies were well understood at that time, the technology for using those frequencies had not yet been fully developed nor exploited. By the time the war ended, however, mainly as a result of the development of radar, the technology had developed right into the microwave region. In the post-war years, the armies of the world had adopted VHF for mobile pack-set use. Because of less critical aerial tuning requirements, VHF had many attractions for this application. Nevertheless, although VHF may have been suitable for the rolling plains of Europe, it proved at times most ineffective in difficult terrain where there were steep hills and gulleys, or alternatively, where there was intense vegetation such as jungle. Problems of VHF were noted both in Korea and Malaya.

Because of these problems, in 1950 the Australian Army set out to have developed a small pack-set for HF transmission rather than for the currently used VHF. In broad concept, it had a number of interesting characteristics. Firstly, the set was not to be mounted on the back, as had been usual for other HF sets, but to be mounted in two basic pouches on the chest of the soldier. The reason for this was to avoid the wireless operator being identified as such in, say, a parachute drop where specialists are a prime target. For the short distance mobile application, a whip aerial was to be used, and for this, ground-wave propagation was applicable.

It was also conceived to have a longer-distance, stationary role, where ionospheric propagation would be applicable. Remembering the war in the Pacific, the Australian Army could, for example, see the use of the set by an observer left on an island to observe passing enemy shipping. Approximately 1W power and a frequency range of 2-10 MHz was specified. Further, the set was to contain four plug-in piezoelectric crystals, giving the operator a choice of four crystal-controlled frequencies, (and further frequencies if he carried additional crystals in a satchel). The set was designed to operate both on double sideband AM telephony and manual morse.

Although the set was bold in concept, it was somewhat conventional in detailed specification. The aerials, so important in making full use of such a small power, were given scant attention. A whip aerial, a dipole and a random length of wire were all that were specified. I imagine that the writers of the specification assumed that an engineer directing a draughtsman for a few small weeks could have attended to all the aerial requirements. Mr W.W. (Wilf) Honnor, then AWA Chief of Research, realising the problems of designing a small pack-set for covering such a wide frequency range, asked that the work should be broader based than anticipated in the specification, and in particular, that the frequencies for ionospheric propagation should be examined in detail. As he saw it, there was no point in covering a frequency range of 2-10 MHz if such was not required. Mr James B. Rudd (later Dr Rudd), who acted as consultant throughout the project, and was at the time Wilf Honnor's Deputy, proposed a ganged variable-capacitor / variable-inductor L-network for matching the valve to the whip aerial resistance; (yes, it was before transistors were available). This arrangement proved to be most effective and was developed further, later in the project. It can be said that Wilf Honnor's suggestion and Jim Rudd's circuit put the A510 on the right track within the first few weeks of the commencement of the project.

In making his suggestion, Wilf Honnor could not have foreseen the very great significance to the A510 which it finally had. After studying the requirements for ionospheric propagation, determining the required frequencies, and predicting the received signal-to-noise ratios, we then set out to do the same type of investigation for ground-wave propagation. In this case it involved taking a large number of measurements in the areas surrounding Sydney. Although this type of propagation was fully understood theoretically, there was scant information available on the effect of trees, hills and buildings, etc in this part of the frequency band. As this work proceeded, I realized the very great problems which would be involved with a small portable set, in having aerials which would be easy to use, but effective in radiating the very small power available. In the case of the whip aerial application, when the set is actually mounted on the chest, the man himself becomes a significant part of the aerial, altering its resistance (almost entirely loss) by a least 2:1, and at times by as much as 4:1; in compensation he also serves to some extent as a radiator himself. The performance changes, whether the man has his arms around the set, or whether he touches the set with his fingers. A special measuring procedure had to be adopted, because with conventional measuring equipment, the equipment itself becomes part of the aerial system and very greatly changes its performance. If I remember correctly, I was the "Standard Man" for these measurements.

In the case of the wire aerials, apart from a large series of measurements carried out on wires of different inclinations and different lengths, on the front lawn of the AWA works at Ashfield, under more or less idealized conditions, measurements were also taken on as wide a range of conditions that could be found around the Sydney area. The rainforest of National Park was used to simulate jungle, aerials were measured over sand, over sea water, when lying down beside trunks of large trees. These measurements gave unexpected and most significant information for the final determination of the aerial arrangements which were adopted.

In the end, I and my assistants (I.H. (Ian) Mathieson and D.E. (Don) Macdonald) in the aerials and propagation group were involved in every aspect of the A510 system from the plate of the transmitter output valve to the grid of the receiver input valve; that is, our work involved the design of coupling circuits, aerials and the study of the propagation paths between the transmitter and receivers. In conjunction with the use of crystal control, the intensive work which started almost by accident, turned out to be the most significant single factor in making the A510 the success it was. In saying this, I donot wish in any way to detract from the great effort of the designers of the very much more complex transmitter/receiver proper. It was a most excellent set, but with the low power available, it would not have been effective had not for the first time the whole problem of transmission, reception, radiation, propagation been integrated as one whole system.
In the aerials of propagation group we recognized the problem, accepted the challenge and were lucky enough to find simple solutions.

With respect to the set proper, the receiver was of high quality and equal in performance to receivers of much greater size. The design involved developing waterproof boxes, specifying and having made special batteries to suit the requirements and the solution of all the problems required to ruggedize a military portable set. The small design team for the A510 was headed by Mr L.K. (Lionel) Curran. One of this assistants was Mr. J. (John) Ward, who was later to play a prominent part in the development of the PRC F1 and PRC F3.

Although Jim Rudd's ganged L network provided an elegant means of matching the whip aerial resistance to the valve of the transmitter/receiver over the whole frequency range of 2-10 MHz, a whip aerial is highly reactive, behaving as a small capacitance which must be tuned at each frequency involved. Whereas the variable inductance for the matching circuit had to have a range of 5:1 in order to match over the frequency range, the whip tuning inductor had to have an inductance range of 25:1 theoretically, and in practice somewhat more than this.

The variable inductor in Jim Rudd's ganged L network used carbonal cores, and a moveable copper sleeve avoided the necessity for having moving contacts. A 25:1 inductance range could not be achieved by this technique, and at first it was necessary to use two inductors in order to cover the frequency range.

In order to reduce dissipation losses, the whip tuning inductors (in series with the whip aerial) were external to the set proper and were kept with the whip aerial itself and the wire aerials in a separate satchel. Having two inductors, gave considerable scope for losing one of them, and steps had to be found for over-coming this problem. It was here that Mr J.E. (John) Bailey (then Chief Engineer of AWA Consumer Products) came to the fore by introducing me to ferrites which were just then becoming part of radio technology. John gave me his first and only two samples of ferrite rods for broadcast-band rod aerials. These rods were subsequently broken into smaller pieces and used for the inductors of the first three or four laboratory models of the A510.

[The first measurements on the ferrite proved their great potential for the particular application. An interesting characteristic of ferrites is that they are sensitive in their properties to the effect of magnetic fields. I got the idea that perhaps we could use a moving magnet as a means for varying the inductance. After carrying out some measurements with a magnet, I put the ferrite rod, (which had been treated like a piece of Dresden china), on the table about 6 inches away from the magnet, whereupon the magnet attracted the ferrite rod which rapidly rolled towards it, finally hitting it and breaking itself into a number of pieces. Thereafter, I quickly rejected the idea !!]

The resistance and reactance of an end-fed wire aerial of any particular length varies very greatly over a frequency range, and for wires of practicable lengths,the resistance varied from some 10 or 20 ohms,when shorter than a quarter wavelength,to 2000 to 7000 ohms,when about a half wave long. With larger sets it is possible to provide the necessary capacitors and inductances in order to tune and match this wide range of impedances, but with a small set like the A510 this is not possible. An alternative is to cut the aerial to a precise length, say 1/4 wave or 1/2 wave at each frequency, but this is not convenient for mobile applications. We found a solution by having a relatively small number of fixed lengths of wire and a small number of switched fixed capacitors. Fine tuning was obtained by slightly detuning the ganged network previously referred to. At first,three lengths of wire were used in different combinations in a manner similar to the use of slip gauges. The danger of this technique was that one of the three wires could get lost. The technique finally adopted was to use the one length of wire with a number of "breaking links". One innovation for greatly improving efficiency was to replace the conventional earth spike by 8 radial wires, 10 ft. long, laid on the ground.

The ganged L-network, designed for the whip aerial, also proved suitable for matching lower-resistance wire aerials of length quarter wave or somewhat greater, when, in addition, a set of switched capacitors was used in series. For wire aerials a half wave, or somewhat less in length, the resistances are high and the L-network is not applicable. For these aerials, the ganged L-network components were used, but the circuit was switched to form a parallel tuned shunt circuit and a second set of capacitors were switched, in this case in shunt with the aerial, in order to tune the aerial reactance.

The work on the A510 commenced in about May 1950. By August of the following year Lionel Curran had assembled the transmitter/receiver and batteries into two cases, designed to be hermetically sealed, and I had collated the aerials and propagation work in a couple of reports, and had prepared a proposal for the aerial system to be used with the A510. We visited Melbourne together and showed the sets to the Army, and discussed our proposal for the aerial system,which was accepted. During the next few months the set was improved to some extent and finalized, and various tests were carried out by ourselves in the Sydney area. The wire aerials, which were designed really for sky wave propagation purposes, were used also as base station ground-wave aerials and we were able to obtain a range of up to 10 miles ground wave(by trying very hard). The following January, that is January 1952, we were permitted to observe the military trials on the first three laboratory models.

[On the day of our visit to Melbourne in August 1951, it turned out to be the coldest day in fifty years, and it was the first time I had ever seen snow falling. During the tests in the following January, it was the hottest day for ten years in Melbourne. Lionel Curran couldn't help remarking that he could understand now why I had left my hometown and had come to live in Sydney].

The trials in Victoria were held in the area surrounding the Balcombe Camp near Mornington, some 25 miles from Melbourne. A base station was set up on the top of a hill; it may have been Mt. Martha itself. During the trials, the HF A510 was compared with similar sized mobile VHF sets. Three sets were used in each of the two frequency bands, one as base station and the other as mobile sets. The tests we observed were for ground wave propagation only, where whip aerials onlywere used with the A510. Each of the mobiles moved down the hill in opposite directions, and communicated with one another and with the base station, both at HF with the A510 and at VHF. After moving about 100 yards on each side of the hill, both the VHF and the HF sets could communicate with the base station. However, the mobile VHF sets could not communicate with one another, the shadowing effect of the (fairly steep) hill being so significant at that frequency. The A510 sets continued to be able to communicate not only with the base station, but with one another when they had each proceeded a mile in opposite directions from the top of the hill. We were encouraged by these trials and returned to Sydney to prepare for the more stringent test to be carried out in Malaya in the following April.

(The Army officer responsible for the trials at Balcombe was Lt. Col. A.W. (Arthur) de Courcy Browne. I found him helpful and encouraging, and it was with much pleasure that years later I renewed association with him when he joined AWA after retiring from the Army).

The party which went to Singapore and Malaya in April 1952 consisted of Lt. Col. D. (Don) Small, (Directorate of Signals, seconded at that time to the Army Design Establishment, A.D.E., Department of Supply), Major R.P. (Bob) Woollard (Directorate of Signals; he retired this year as Major General Woollard), and Major R. (Roy) Coutts, (Directorate of Infantry), together with Lionel Curran and myself as civilian observers. The report written on return from this three weeks visit is appended. Apart from documenting the technical results of the tests, it includes a considerable quantity of background information, so that only a relatively few comments will be made herein.

The tests were carried out from the British Army, jungle training camp, Farlef Training Centre, Kotta Tingi, in Malaya, 25 miles north of Singapore. This time was during the period of bandit activity; in fact, one purpose was to carry out tests, not only in tropical conditions, but also where military action was also taking place. Instructions received on our arrival in Singapore permitted the civilian members of the party to go only into "safe" areas. Bandit activity existed over the whole of Malaya at that time, and the instruction was interpreted to mean that we were free to move only on Singapore Island itself and in the area occupied by the Farlef Training Centre. This was a disappointment to us, since it meant that we were unable to observe at first hand the problems of communicating in primary jungle.

Nevertheless, we had the important task to perform of running the A510 base station at the Farlef Training Centre (F.T.C.), and were kept busy documenting the technical results of the trials, and when the field team split into two, we, in fact, had the best overall picture of what was going on; we were able to communicate with each group when, at times, operating on whip aerials, they were unable to communicate with one another.

Also, we learned much from people we met at the F.T.C. The F.T.C. was a centre not only where troops trained for the jungle action in Malaya, but where staff had an intimate and detailed knowledge of the conditions existing in Malaya. People came and spoke to us as the tests were going on. We were permitted to see a demonstration of a jungle encounter, enacted by the Gurkhas who were stationed at the F.T.C.

[Observing the need to pay attention to the "civilian guide" during the "attack", we realized that had we been permitted to go into the jungle during the tests, and had there been a real attack, we may well have endangered the lives of our military colleages].

The results of the tests were very encouraging, the A510 proving to be superior to the currently used WS68 sets. It was also interesting to note that, although the 68 set did not have an especially designed kit of aerials, as did the A510, operators in the field had found it absolutely essential to pay particular attention to aerials if they wished to obtain communications.

Lt. Col. Shirly, a New Zealander with the British Operational Research group in Malaya,had gone to the extent of developing a dipole array out of 300 ohm television ribbon, in an attempt to improve communications.

On arrival at the F.T.C., I arranged a "cut" dipole for the most important operating sky-wave frequency. Because of the difficulty of "cutting" a dipole in the field, I could find little interest in its use in Australia, but it proved so successful in Malaya that on return we were pressed to design an adjustable dipole, which we ultimately succeeded in doing.

For further discussion on the trials reference is made to the Report attached as Appendix A.

[Five photographs were included with the original report. A few more have now been added. One with the writer fully equipped with a jungle pack and the then currently used WS 68 set. When I protested "If you want to take a photograph why don't you get a real soldier", I got the reply "but we want you to know how heavy it is, so that you'll go back and design lighter sets". Although it may have been too late to influence the A510, I found that it made me more sympathetic years later when many months of effort were required to reduce the PRC/F1 by a few inches in size and a few pounds in weight].

Shortly after our return to Australia, the A510 was taken over by the engineers in the AWA Consumer Products (CP) factory at Ashfield, to prepare it for mass production. Although the laboratory models may have looked almost identical to the final production sets, a great deal of detailed modification and refinement was required before the A510 could be made from mass-production tools.

Mr R.A. (Roy) McMaster was at first responsible for this work in CP, but when he was transferred to work on (the then coming) television, Mr R.D. (Ron) Stewart (now AWA Assistant General Manager in charge of the Engineering Products Division) took over the task. One of his assistants was Mr C.F. (Col) Platt, (now Works Manager of the AWA Ashfield Division). A year later, 1953, Ron Stewart went to Malaya, with Lt. Col. Don Small, for tests on the first production prototypes. Ron Stewart has described this visit in a separate statement.

With respect to the AWA Research Laboratory, after the tests on the laboratory models in Malaya, Lt. Col. Don Small had arranged for a separate contract to continue investigations into aerials for small man-pack sets, and a large draft handbook on aerials was prepared. Although the handbook was never printed, the information contained in the draft, together with the earlier A510 reports, is still the best set of collated information available to me on aerials for this type of application.

Special mention should be made of the significance of Don Small to the A510 project. He was associated with the A510 throughout almost the whole of the Laboratory and production development phases. Whereas Wilf Honnor had the foresight to suggest a broader based study than implied in the original A510 specification, Don Small had the wit to grasp the significance of this work and to give it his wholehearted support and encouragement, and it fell upon him to persuade his colleagues to provide the necessary funds for the additional work. I believe it was also due to his efforts that we were permitted to observe both the Australian and Malayian trials.

Whereas the use of the four piezoelectric crystals in the A510 was of very great importance in providing stability, and in avoiding the need for netting a group of transmitter/receivers, the one set of four crystals cannot be used, without causing interference, when a large number of A510s exist in the one area. This presents a considerable logistics problem for the Army. The solution finally had to await the PRC-F1, with its synthesiser and 10,000 crystal-controlled channels.

The PRC-F1 development was again carried out in the AWA Research Laboratory and the A510 work gave us a flying start.

The specification for the PRC-F1 (at first named the A512) again called for A510 aerials. By this time, Jim Rudd was in charge of the Research Laboratory and took a daily interest in the work involved. Wilf Honnor, by now AWA Chief Engineer, also took part in all formal meetings. Mr J.F. (John) Allen was the project leader and John Ward his lieutenant.

Don Macdonald and I were again involved in the design of the aerial coupling circuitry which this time was quite complex; the external aerial coupling box for this higher power set is as large as one of the two A510 cases. Following the development of the PRC-F1, John Ward (by then in E.P.), continued to work on improvements resulting in the PRC-F3, (a PRC-F1 with improved synthesiser) which only ceased production in 1977.

Thus, work which commenced in 1950, and was carried out in a fundamental manner with considerable thoroughness, has had influence on the Army, and on AWA and its people, for more than a quarter of a century.

APPENDIX A

TO

R78-28 "NOTES ON THE A510"