Antique Wireless Association of Southern Africa

215 June 2024

Drake 2B Receiver

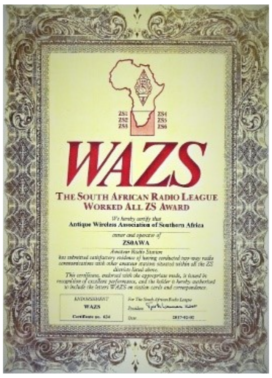
The **R. L. Drake Company** is a manufacturer of electronic communications equipment located in Springboro, Ohio. It is also known for its line of equipment for amateur radio and shortwave listening, built in the 1950s through the 1980s. The company operates as a separate entity owned by Blonder Tongue Laboratories, Inc.

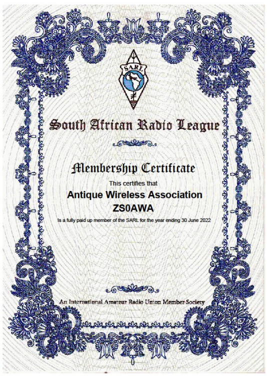
The company was founded in 1943 by radio design engineer Robert L. Drake. The company began as a manufacturer of low pass and high pass filters for the government and amateur radio market, and after World War II, produced amateur radio transmitters and receivers and communications receivers for maritime mobile service.

Amateur stations made up of Drake gear were used on a number of record-breaking hot air balloon flights, the RMS *Queen Mary*, and the Rutan Voyager. Many of the Drake receivers, transmitters, and transceivers manufactured in the 1950s, 1960s, and 1970s are still in active use today. When founder Robert L. Drake died in 1975, the operation and management of the company was turned over to his 2nd son, Peter W. Drake.

The Drake 1A receiver was the company's first meant specifically for radio amateurs. Introduced in 1957, it was revolutionary in at least two ways. First, it was much smaller than most receivers of the time period. The design emphasized simplicity and ease of operation. Second, it was designed specifically for reception of the relatively new and increasingly popular single sideband (SSB) mode of voice transmission.

In 1959 they followed the 1A with the 2A, a more traditional looking receiver that was a bit larger but still much more compact than its contemporaries. The 2A had more features, increased sensitivity and selectivity, and was introduced at the same price as the 1A. It was followed two years later by the 2B, very similar in appearance but with improved performance and a new set of controls for adjusting the selectivity (bandwidth) and center frequency.





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AWA Committee:

Visit our website:
www.awasa.org.za

Reflections:

In a couple of days we will be into the next half of the year, officially, with the solstice on the 21st June.

Winter has come a bit late but here in the far reaches of the Northern Cape, I was not sure if they knew what winter was. I was quite surprised when it did get cold though. You could kind of say it caught me with my pants down and for the first time this year I'm wearing long pants again.

The CME's have come and gone and done their damage to the bands, which seemed to also have changed rather suddenly. One day 40m was working up to 8 o'clock, and later, at night, the next day it was out by 6 and our 7 pm CW sked was moved to 80m. Which was not great at first, but seems to be slowly improving.

I am always reminded of Om Rod who used to say that 80m may have not been the best band, but it was the most dependable. It was he who introduced the 80m nets and encouraged us to play mf's, as he would using a turntable and old records that he would dig out of storage, on a Gonset GSB100 AM transmitter.

I must admit, we kept the band quite busy in those days, and 80m was not used as just a second thought, there were regular nets and calls done there. Today, if 40m is not working people pack their radios away in the cupboard.

It seems as though we have been through a rough path the last few years with band conditions. The Green guys will blame it on global warming, the other guys will blame it on low sunspot activity and somewhere along the lkine there is actually what the problem is. Don't ask me, I'm a fence sitter, so I'll take whatever sounds plausible.

But that we have not had great conditions locally, is real but the Dx bands have been quite active. I don't know how many of our readers are keen Dx'ers, but I am sure there must be a few.

10m has been very active this last 2 years, a band that I had never really worked at all, until I discovered how active it was and made a good few Dx contacts during that time. But of course, this last period, the bands are not great. The results of the AWA Valve QSO party are published in this Newsletter and it was quite surprising there were a good number of stations on this year. AM still seems to be a bit of a sticky one, and although there were not too many stations active, there were only 4 logs submitted.

Ludwig, ZS5CN took all the honours this year with his full complement of all valve radio's in his hideaway in the mountains.

It was good to hear so many active stations on SSB, but once again only a few logs were submitted.

The next Valve QSO party will be in October, so lets hope by then there will be an improvement in conditions and there will be a few more stations taking part. Also gives you enough time to get your AM rigs up and running and tested.

Not forgetting of course your SSB rigs too. Remember, the more Valve oriented the better the score. It just gives you that better chance to double or treble your score and get a really nice AWA certificate for your efforts.

I don't know if that is much incentive, but who knows ?

73

DE Andy ZS3ADY

Coronal Mass Ejection (CME) Wikipedia

CMEs have been observed indirectly for thousands of years via aurora. Other indirect observations that predated the discovery of CMEs were through measurements of geomagnetic perturbations, radioheliograph measurements of solar radio bursts, and in-situ measurements of interplanetary shocks.

The largest recorded geomagnetic perturbation, resulting presumably from a CME, coincided with the first-observed solar flare on 1 September 1859. The resulting solar storm of 1859 is referred to as the Carrington Event. The flare and the associated sunspots were visible to the naked eye, and the flare was independently observed by English astronomers R. C. Carrington and R. Hodgson. At around the same time as the flare, a magnetometer at Kew Gardens recorded what would become known as a *magnetic crochet*, a magnetic field detected by ground-based magnetometers induced by a perturbation of Earth's ionosphere by ionizing soft X-rays. This could not easily be understood at the time because it predated the discovery of X-rays in 1895 and the recognition of the ionosphere in 1902.

About 18 hours after the flare, further geomagnetic perturbations were recorded by multiple magnetometers as a part of a geomagnetic storm. The storm disabled parts of the recently created US telegraph network, starting fires and shocking some telegraph operators.

Technology and the Antique Radio Revival

Richard Dismore F4WCD/ZS6TF

The Antique Wireless Association of Southern Africa is a phenomenon defying conventional wisdom and is without parallel in the world of amateur radio. Where else can you belong to an association relating to any hobby that has a globally accessible meeting every week, has a newsletter every month, a world class museum, technical discussions and support, facilitates acquisition of artefacts and spare parts, and an ultra-functional website rich in information,…at no charge!

The origins are deep rooted

South Africa is a country twice the surface area of France, where the distance between its' two biggest cities Johannesburg and Cape Town is nearly equal to London-Rome. 1700 km long, and 1600km wide, South Africa was an early adopter of amateur radio albeit beginning with a handful of enthusiasts. The SARRL (South African Radio Relay League) was formed in 1925 modelled on the ARRL after commercial, broadcasting, and amateur frequencies were legally segregated. A leading figure was John Streeter of Cape Town, the first to make contact with the USA in 1925, and who gained the ARRL WAC award shortly afterwards. The growth of the hobby was remarkable and although the name was changed to SARL (South African Radio League), the practise of relaying was widespread and continues to this day including all the southern African countries, Mozambique, Zimbabwe, Zambia, Botswana, Namibia, Malawi, Lesotho and Swaziland.

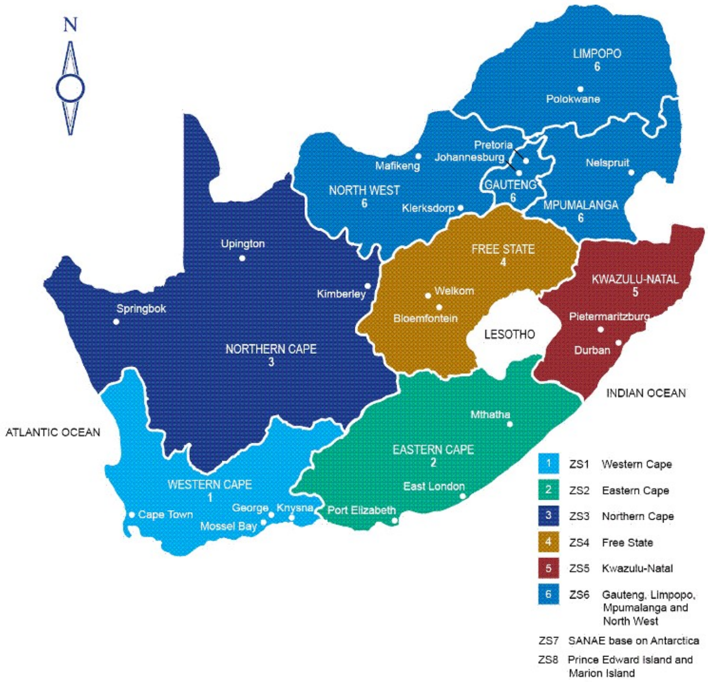

Figure 1: The callsign areas of South Africa

From little acorns, Oak trees grow.

In March 2000 4 amateurs who operated Collins equipment discussed in Pretoria the formation of a Southern African Collins interest group**[1]** and agreed to start a weekly 40M SSB net each Saturday morning. Soon all the known SA Collins owners had been contacted and the group grew to about 20 members including one from Harare Zimbabwe. Two years later the 3rd newly elected president of the group Rod Radford ZS5RK realised it had reached its limit and proposed the extension to operators of other makes of antique radios.

On 22 March 2003, the Southern African Collins Interest Group was incorporated into the new "Antique Wireless Association of Southern Africa", with Cliff ZS6BOX convener of the original group of 4 as Founding President **[2]** and Willem ZS6ALL member of the original 4 continuing as Net Controller from his Kempton Park station. Rod also penned an elegant mission statement with a unanimous approval, and Allan Franzsen ZS6BIK obtained the association's special callsign ZS0AWA, which was first used in August of 2003.

AWASA mission Statement

Our aim is to facilitate, generate and maintain an interest in the location, acquisition, repair and use of yesterday's radios and associated equipment. To encourage all like-minded amateurs to do the same thus ensuring the maintenance and preservation of our amateur heritage.

Membership of this group is free and by association.

Organic growth

The association grew organically as amateurs re-discovered and repaired their old radios, more came back into circulation and the following milestones and improvements were achieved.

40 metres was inadequate to serve such a large area alone and relays on 20 and 80 metres were implemented.

PRO Andy ZS6ADY began the mailed-out newsletter in January 2006 and designed the Association's logo in 2007.

Barry ZS6AJY started a weekly 40M CW net on Saturdays.

AM enthusiasts began a net on 3615kHz on Wednesday evenings including short test transmissions of music for periods up to 3 minutes with a 6 minute interval, that were permitted on 80M uniquely by the SA regulations. These were known as MF transmissions (Musical Frequencies).

Willem ZS6ALL introduced an AM only net on 3615kHz which ran for an hour before the start of the SSB net on Saturdays.

An active chapter of AWASA in division 5, KwaZulu-Natal was created by Rod ZS5RK and his son Don ZS5DR

The author became involved in the association in 2008 with the display of equipment at the AWASA open day at the Transvaal Aviation Club at Rand Airport in April. For the next 3 years he wrote bits for the newsletter, and was a regular net participant.

Figure 2: AWASA open day display at TAC Rand Airport May 2008

An imperceptible change in direction.

In 2011 the committee approached the author to become the next President of the association. This was fairly forcefully declined on the basis that since retiring in 2003 he had commuted to France between mid-June and mid-September so could not come on net or participate personally for 3 months of the year. The unsaid reason was that he had been in committees of some sort most of his life and was content to be an ordinary member. The legs of the official reason were knocked out from beneath him by Kevin ZS6KAT who proposed to enable his TS850 for Echolink **[3]** by building an interface to provide remote operation of his station on the 40M net from a laptop via the internet, since he would be on it anyway. Kevin was a mobile phone company technical executive with a flair for homebrew. Anything he restored or built had "Swiss watch" precision and quality. This was tested and was very workable so the Author was AWASA president from 2012 to 2013. Effectively the Laptop in France performed the function of a remote microphone and speaker with Kevin patching the audio to and from the transceiver as well as cueing the remote station in to the net controller.


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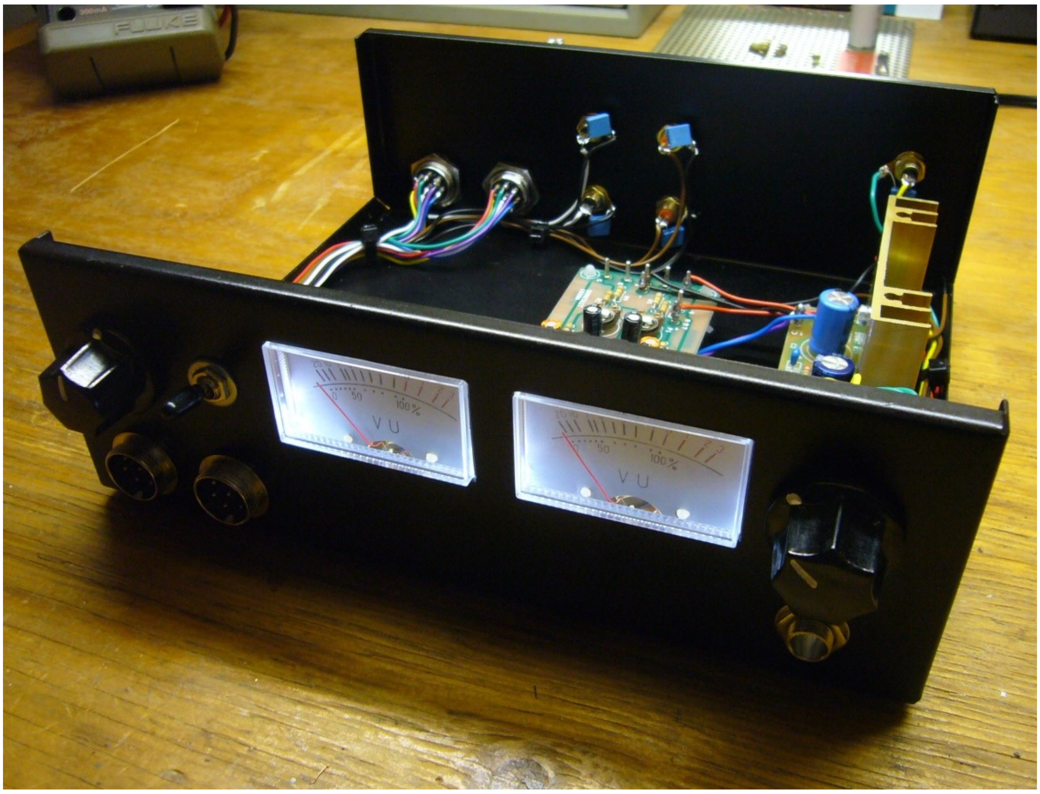

Figure 3: ZS6KAT Echolink HF radio interface.

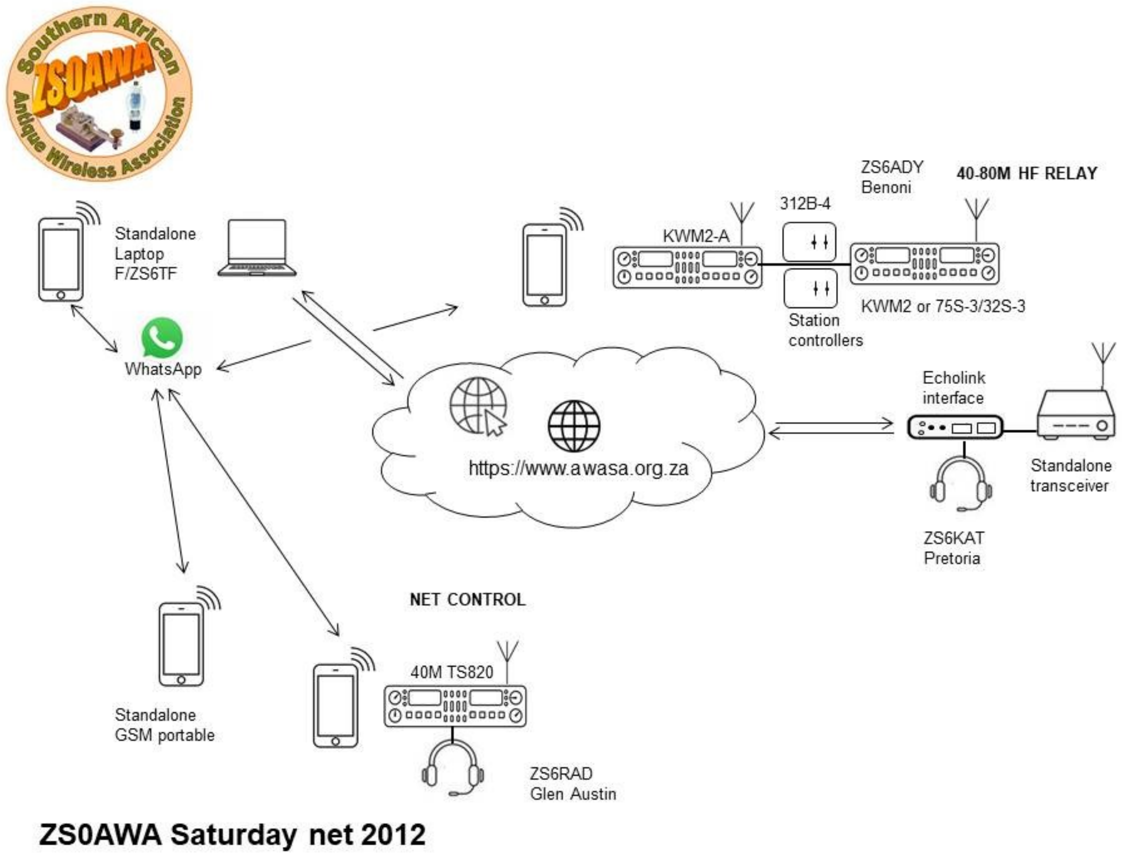

Figure 4: The first Echolink connection to the AWASA HF only **[4]** net June 2012

When the author first came on the net with the call F/ZS6TF it caused very little comment and it was seamless business as usual. During the authors' tenure, 3 far-reaching interventions were made.

The first was to introduce a topic on the Saturday morning net which has been a draw-card feature ever since.

The second was a tweak to the mission statement to introduce "***and associated equipment"*** to yesterday's radios.in order to widen the membership to collectors of test equipment, audio gear and accessories such as Morse keys.
The third was to set up the alliance with the SAIEE (South African Institute of Electrical Engineers) which resulted in the establishment of a world class museum in the SAIEE headquarters, Innes House with its own station ZS6IEE.

Figure 5: Past AWASA president ZS6TF handing over to the museum the AWASA donation of an original J Fluke true RMS hollow-state electronic meter to the late Max Clarke, Chairman SAIEE historic section. November 2013

Figure 6: A collage of the ZS6IEE antenna mast crew, ZS6JPS, ZS6KAT, ZS6MC and ZS6TF atop the tower.

Figure 7: 2024 AWASA President Jacques ZS6JPS operating ZS6IEE with John Streeter's original receiver in the display case mid right.

Figure 8: The ZS6IEE QSL card featuring Innes House a Herbert Baker Building from 1910 which houses the museum and the amateur radio station.

AGM's have been conducted in the professional environment of the SAIEE boardroom since that time, and an AWASA support team was formed to promote and maintain the museum.

The medium of off-net communication for operations was the mobile phone application WhatsApp. The newsletter by then was an electronic version only and relays were taking place on 30M where SSB was permitted in the local regulations. John ZS1WJ moved to Kleinmond from Benoni and established a new AWASA chapter in the Western Cape.

Stepping up a gear

Meanwhile, Kevin became the emissary for Echolink doing presentations at radio club functions and his GSM industry colleague Henry ZS6MC was instrumental in cooking up an AWA server ZS0AWA-L which was installed in the basement of his apartment block. He also was treasurer of the Sandton Amateur Radio club which had a 2M repeater on top of the Bryanston water tower which was visible from the Author's house. It was soon equipped with Echolink and through Henry's influence it was made available as an additional relay for the AWA Saturday net. The outside resource that managed the AWASA website passed away and then AWASA President Jacques ZS6JPS took on the task and developed it into a world class resource.

The author emigrated to France in June 2016 relinquishing the museum responsibility to Oliver ZS6OG backed up by Jacques.

The net server struggled along for a few years, its underground car-park location suffering from sub optimal internet service, was RF unfriendly, and only just tolerated by the residents association. Renato ZS6REN (President 2021 to 2023 inclusive) recomposed it at his Sydenham QTH and gave it an extra job to provide Echolink connectivity to the Kempton park repeater. Renato being a test equipment specialist and collector did not have to think up topics. All he had to do was look at his bench! At some time Rad ZS6RAD, net controller had re-purposed an audio mixer as an interface for relaying and cross connecting to Echolink. When Chris ZS6GM then living in Hoedspruit, became active on the net, he perfected the mixer set-up ringing the changes on 3 different transceivers for relays. His early background in RF equipment and antenna design (Racal). And later owning the "LM radio" popular station meant that the technical topics were elevated to a new level. Furthermore the audio quality of the net system improved due to his influence, commanding voice, and use of decent microphones. When WhatsApp faced security difficulties and a change in user terms, during the Covid period, Andy now ZS3ADY having moved to the northern Cape, migrated the AWASA to Telegram. This is a much better, more secure service running equally on PC and mobile platforms. It provides file interchange, and often is very active with show and tell and documentary contributions synchronous with the net.

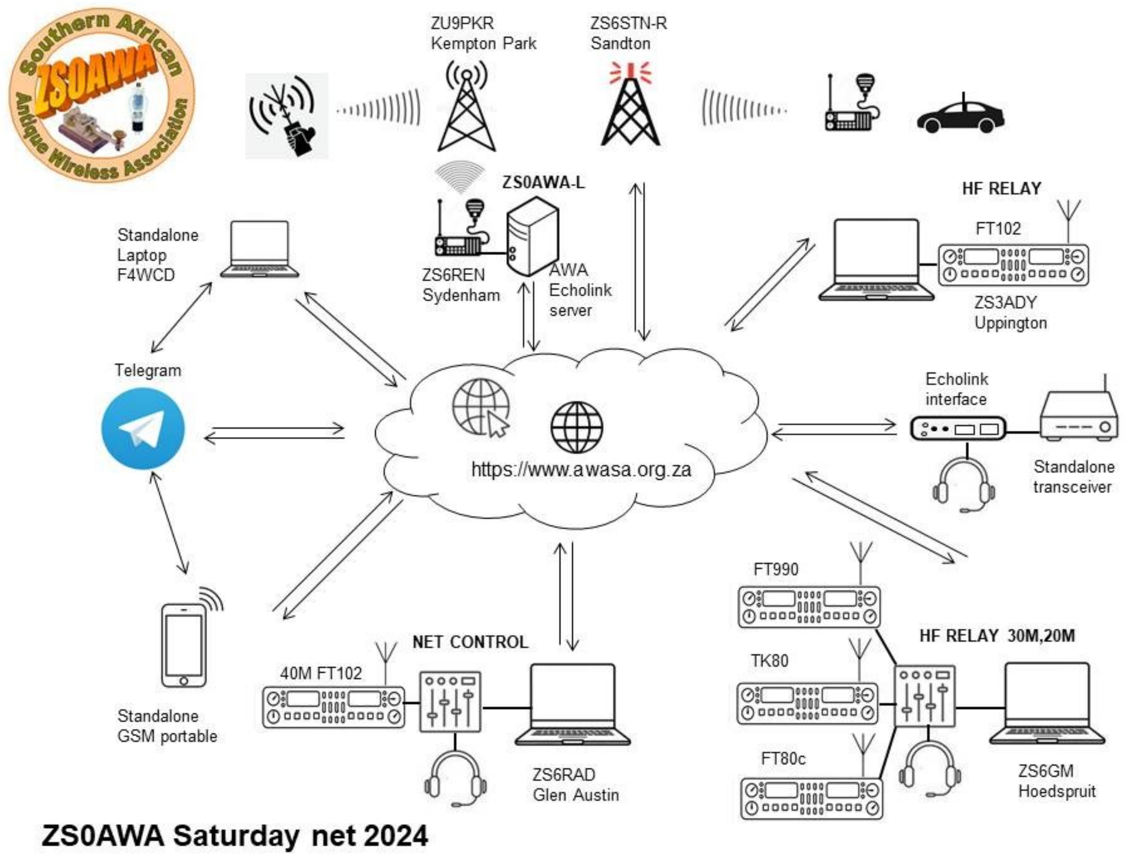

Figure 9: The ZS0AWA Saturday morning network at end March 2024

Concluding remarks

Figure 9 is a snapshot and the net is expected to evolve and morph in time to adapt to changing circumstances. In fact it already has. For the first net in April 2024, Chris ZS6GM, who had moved QTH to White River, cobbled together a temporary 40M relay station on the kitchen table feeding a temporary magnetic loop antenna with little loss of functionality. Even with the plague of unreliable mains power in South Africa, the AWASA network has sufficient redundancy to recompose itself if sections fall apart.

Other public VOIP communication systems have been around for a while, for example Skype and Facetime. Undoubtedly Zoom is the best conference and meeting technology which reached its supremacy during Covid, and has been adopted by a number of radio clubs for meetings and seminars. It is designed for meetings with strict chairman control, and it lends itself to instruction in a classroom under instructor control. Its software enabled audio switching and level protocol can and does cause channel grab by coughing, extraneous noises, noisy backgrounds and loud voices risking that a general discussion may descend into chaos. This can be mitigated by applying by strict net control and muting rules but results in an unnatural mode of operation. The Author last year did a one-hour presentation over Zoom to the LICW (Long Island CW Club) talking to a large number of Powerpoint slides. The Questioners were then called in one at a time by the organiser and this was entirely satisfactory.

On Friday 3rd April the author participated in the Alan Turing webinar lecture at Kings College, Cambridge. The presenter's audio was pretty good throughout but at question time, whoever was controlling the microphone mixer got into a competition with Zoom's ALC. The audio broke up so badly at times I could only guess at the question from the presenter's answer.

Echolink was designed by and for radio hams and access is obtained by sending a copy of a current valid ham licence making it exclusive. Its operation is intuitive for radio amateurs and very versatile in the ways it can connect. In a net, sked, or QSO scenario, behaviour remains the same, just the space bar substitutes for the PTT. Non ham members can listen on the relays. Andy, the AWASA PRO records the net now and it can be downloaded from the website for those who missed it or want to go over a particular point again by dragging the time bar. They are listed under the "Latest News" tab.

The figures speak for themselves. At its peak South Africa had more than 4000 radio amateurs, whose number has now declined to circa 2300. In contrast, AWASA membership has come a long way from the initial 20 in 2003 to 432 at 1st January 2024. The net as described in Figure 9 affords reliable country and international reach, and the interest in the topics sustains and grows the membership, a platform for new and old amateurs alike with a perfect blend of vintage radio and new technologies.

References

[1] https://www.awasa.org.za/about A brief history of AWASA Cliff Smyth, ZS6BOX

[2] Past AWASA Presidents

2003	Cliff Smythe	ZS6BOX
2004	Bushy Rhoode	ZS6M
2005	Gary Potgeiter	ZS5NK
2006	Rod Radford	ZS5RK
2007	Andy Cairns	ZS6ADY
2008-2009	Rad Handfield-Jones	ZS6RAD
2010-2011	Don Radford	ZS5DR
2012-2013	Richard Dismore	ZS6TF
2014-2015	Ted Hart	ZS6TED
2016-2017	Jacques Scholtz	ZS6JPS
2018-2019	John Watson	ZS1WJ
2020-2023	Renato Bordin	ZS6REN
2024	Jacques Scholtz	ZS6JPS

[3] https://echolink.org/

[4] In figure 4, your attention is drawn to the ingenious relay station operated by Andy, ZS6ADY at the time. He connected his Collins S-line equipment through 2 station controllers originally designed for phone patching, using the 600 ohm line connections for audio transfer and switching.

RESULTS OF THE AWA VALVE QSO PARTY

Following are the results of the AWA Valve QSO Party held on 04 and 05 May 2024

AM:

1. Ludwig Combrinck ZS5CN – Collins 32V-1
2. Andre Botes ZS2ACP – Yaesu FT101EX
3. Hennie Veldman ZS6HAV – Viking Ranger
4. .Theunis Potgieter ZS2EC – Kenwood TS570

No other logs were submitted, although there were 29 stations active.

SSB:

1. Ludwig Combrinck ZS5CN – Collins KWS-1/75A-4
2. Nico Oelofse ZS4N – Yaesu FT101
3. Mario Beltrame – Yaesu FTdx400
4. Theunis Potgieter ZS2EC – Kenwood TS570
5. Bruce Rowan ZS6BK – IC7300
6. Gert du Plessis ZR6GRT- Kernwood TS570s

There were 55 stations active and 6 logs submitted.

Congratulations to the top scorers.

Radio Communications Through Rock Strata – South African mining experience over 50 years

Brian A Austin

Significance:
The pioneering work done in South Africa in developing radio communications technology for use underground in mines is summarised. Propagation took place, in the main, directly through the rock strata with incidental coupling into power cables, pipes, rails and other conductors. The research established the optimum frequencies for communications as well as the most appropriate antennas. Specialised radio equipment was developed for this task as constrained by the technology of the time. Size and weight were major constraints; ultimately, handheld equipment, using single-sideband modulation, was produced that functioned exceptionally well in numerous situations underground.

Introduction

It was early in 1938 that the medical superintendent of Rand Mines, Dr A.J. Orenstein, asked Professor Basil Schonland, the Director of the Bernard Price Institute of Geophysical Research (the BPI) at the University of the Witwatersrand, about the feasibility of radio communications underground in mines. Orenstein had long been concerned that firefighting and rescue teams were severely hampered by a lack of communication between those personnel and anyone else when they ventured into the most hazardous of situations. Schonland was sceptical that radio signals would propagate over useful distances through rock strata, but agreed to investigate.[1,2]

The war, radar and the Special Signals Services

International events soon intervened as war with Nazi Germany loomed. South Africa declared war on 6 September 1939, just three days after Britain. From then, the research focus of the BPI shifted inexorably. Henceforth, all its resources, as limited as they were, would be given over to the investigation of RDF, or radar as it was known in those earliest days (see Figure 1). What followed, was the formation of the Special Signals Services (SSS), as part of the South African Army's Corps of Signals with Lt Col Schonland as its commanding officer.[2,3] And immediately, the SSS co-opted the services of engineers and physicists from South Africa's major universities – one of whom was a young engineering graduate from Durban by the name of Trevor Wadley.

The development of South Africa's own radar equipment and its deployment, along with subsequent British radars, around the country's coastline as well as in East Africa, the Middle East and in Italy, has been reported extensively elsewhere.[2-4] It was that massive wartime effort at the BPI that was the spur to the formation of the Council for Scientific and Industrial Research (CSIR), which was formally established in October 1945 with Schonland as its President. And the CSIR's first specialist laboratory to come into existence was the Telecommunications Research Laboratory, with Wadley among its first members of staff.[5]

Wadley and radio underground

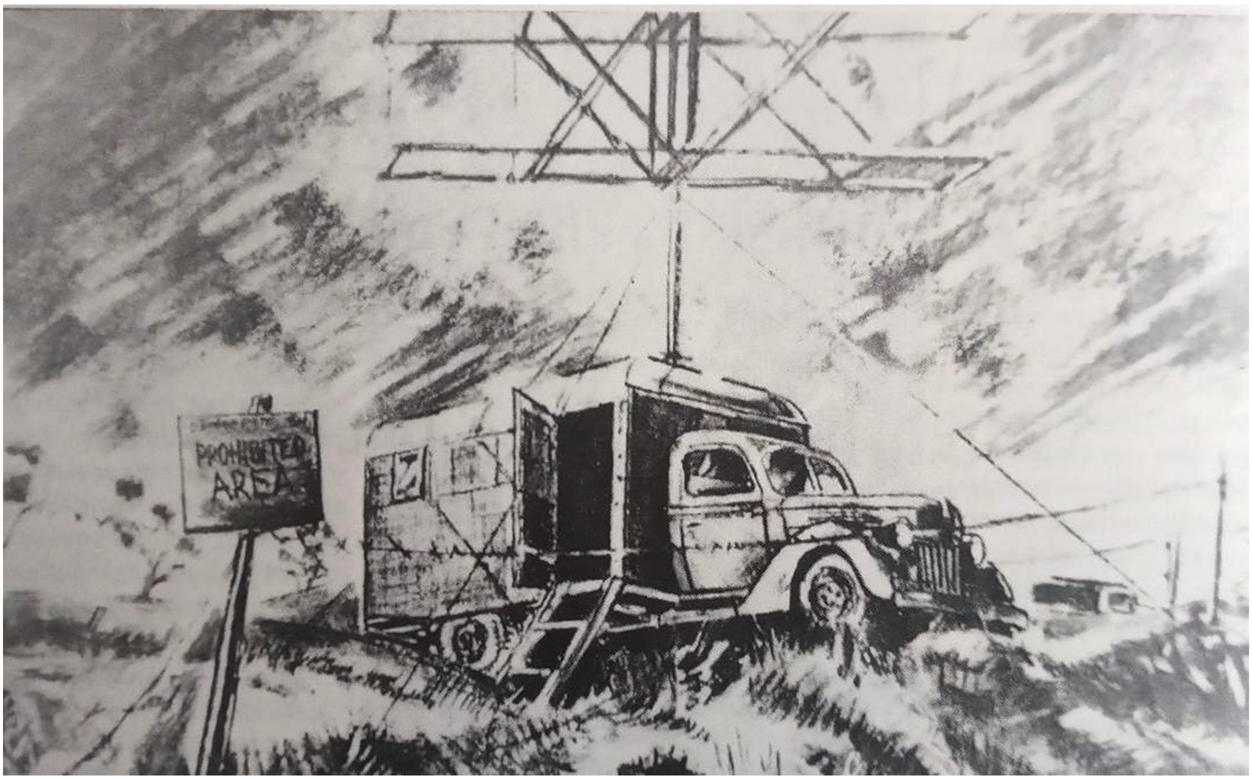

Figure 1: The mobile radar system designed and constructed by the Special Signals Services at the Bernard Price Institute of Geophysical Research, University of the Witwatersrand, in 1942.

Wadley's genius was soon evident. He designed a revolutionary type of radio receiver that became the mainstay of British naval communication when the equipment was produced by a British company. Subsequently, he developed a distance-measuring device of quite unparalleled accuracy called the Tellurometer which revolutionised the field of surveying.[5,6]

Remarkably, he also turned his attention to the problem of radio communications in mines that had first been raised almost a decade before.

In 1949, Wadley wrote a report for the Transvaal and Orange Free State Chamber of Mines describing the outcome of his research and his recommendations for suitable equipment.[7] The important question he answered was what the optimum frequency was in order to achieve maximum communication range directly through the rock. Reliance could not be placed on signals propagating via the underground tunnels because of their irregular shapes, their curvature and roughness, which ruled out line-of-sight communications.

Electrical properties of rocks

In order to determine how electromagnetic energy might propagate through the lossy dielectric medium of rock, one requires a knowledge of its propagation constant γ where:

$$\gamma = \alpha + j\beta = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} .$$

Here α is the attenuation constant, β is the phase constant and $\omega = 2\pi f$ is the angular frequency. The other terms are the fundamental electrical parameters of rock: its conductivity (σ), dielectric constant (ε) and magnetic permeability (μ). Of these, only the permeability remains constant with changes in frequency, while most geological materials are also non-magnetic.[8] By contrast, both rock conductivity and dielectric constant are frequency dependent.[8,9]

Wadley measured both the resistivity (the reciprocal of conductivity) and the dielectric constant of quartzite and some shales typical of the gold mining region of the Witwatersrand. He used borehole samples with apparatus specially designed for the task. In his report he showed how the resistivity of quartzite varied from about 9×10^4 to 5×10^3 ohmmetres over a frequency range from 100 kHz to 3 MHz. By contrast, the dielectric constant hardly changed and had a value of about 6. Using these data, he calculated the attenuation of a radio signal propagating through 300 m of quartzite and showed how it increased rapidly with frequency, implying that the lower the radio frequency, the better for communicating through rock.

Antennas in lossy media

The fact that the antennas would be surrounded by rock complicated the situation considerably. Wadley considered that a long centre-fed dipole antenna laid along the tunnel floor, or footwall, would be an appropriate antenna for a fixed station underground. For the portable equipment he chose a frame aerial which is essentially a loop of wire (perhaps of many turns) that would be wound around a miner's helmet or 'hardhat'. He measured the impedance of the dipole at a particular frequency and attributed the results to the electrical characteristics of the surrounding rock. From those measurements he deduced the antenna's loss from 10 kHz to 10 MHz. As expected, there was a trade-off, between the rock-induced loss and the improved performance of the antenna as its apparent length, relative to the wavelength, increased with frequency.[7]

By contrast, the small loop antenna was difficult to treat theoretically because the interchange of energy between the air-space and rock was not well understood. This was undoubtedly true and it was to be many years before the underlying electromagnetics principles affecting such electrically small antennas, when immersed in lossy dielectric media, were fully explained.[10,11]

The optimum frequency

Wadley produced a graph of the total loss in decibels (dB) suffered by a radiating signal over a distance of 900 m for frequencies between 30 kHz and 3000 kHz. The graph went through a distinct minimum at about 300 kHz, which, therefore, is the optimum transmitting frequency for that particular distance. The graph also showed that for communications over greater distances a lower frequency would be required, while a higher frequency could be used over shorter distances.[7]

As in all radio communication systems, it is not just the strength of the signal that determines optimum performance but rather the signal-tonoise ratio. A deep-level mine presents an almost unique environment from a noise point of view. The great thickness of the overburden removes, almost completely, any electrical noise generated above ground (including by lightning) and therefore the only noise will be that caused by nearby electrical equipment and within the radio receiver itself. In the case of mining emergencies, all electrical power is usually switched off in the affected area, leaving just the receiver-generated noise which can be reduced substantially by careful design.[7]

The radio equipment

Wadley recommended that two types of transmitters be developed: a static set, producing about 4W of power to be used at a fixed point underground where it could make use of a fairly long antenna; and a portable set, generating only a tenth of the power and using a considerably smaller antenna. Naturally, each transmitter had its companion receiver, with each being of a modern superheterodyne configuration for optimum performance. Based on those specifications, he predicted that the normal operating radius would be about 600 m. A workable signal should still be received at a distance of around 750 m, while the absolute limit would be about 900 m. An appropriate transmitting frequency should be about 350 kHz.[7]

Because the radio technology of those days was all based on thermionic valves, the equipment would naturally be rather bulky. Wadley estimated that the larger unit would weigh no more than 14 kg, while its portable counterpart might be about a third of that.

Wadley never published his results in the open literature. This was an unfortunate omission because there was a real dearth of such quantitative data at that time.

An industrial hiatus and a mining catastrophe

It was not until the late 1950s, on the formation of what was to become the research laboratories of the Chamber of Mines, that Wadley's recommendations received serious attention from the South African mining industry. The problems foreseen by Dr Orenstein all those years before had by no means gone away: if anything, the expansion of the postwar gold and coal mining industries, and the stepped-up production then taking place, had exacerbated the problem of underground fires, accidents and, of course, the ever-present risk of rock falls at the increasing depths at which gold was being mined. On 21 January 1960, a disaster occurred at Coalbrook Colliery in the northern Free State when the mine workings collapsed, entombing 435 men, all of whom perished. Immediate attempts to rescue them were set in train with the Mines' Rescue Brigade of 250 men leading the effort. These highly trained personnel were all experienced miners who had volunteered for the dangerous task of firefighting and rescue

work underground. They were trained at the Chamber's Rescue
Training Station in Johannesburg.[12] However, once they went underground, those rescue teams were without any form of communication.

Designing the equipment

The underground radio project had been resurrected by the Electronics Division of the Chamber's laboratories during the late 1950s. Wadley's findings and recommendations underpinned their work. Their own calculations had confirmed that a system loss of 150 dB between transmitter and receiver was tolerable and the family of curves in Figure 2 indicated the optimum frequencies for particular distances between them.[13]
Despite the decade or so that had elapsed since the invention of the transistor, and its rapid embrace by many sectors of the electronics engineering industry, the germanium transistors of that era were still limited to low-frequency and relatively low-power applications.
They were also thermally sensitive devices, which was an important consideration to be born in mind given the very high temperatures experienced in deep mines. The radio equipment would be used by members of the Mines Rescue Brigade, known as 'Proto teams' because of the Proto breathing apparatus they used. It required its user to clench a snorkel-typebreathing tube between their teeth and to wear a nose clip. Both made speech impossible. This restriction had a great bearing on the design of the radio equipment. Standard practice during mine emergencies was to establish a so-called fresh-air base, as close as possible to the disaster area, where breathing apparatus was not required. The Proto team, carrying the portable radio equipment, would then go forward from there to carry out its task.
An amplitude-modulated (AM) transmitter was designed for use at the fresh-air base. The frequency allocated by the Postmaster General for mining applications was 335 kHz. The transmitter's output power was approximately 5 W. To exploit the very low noise conditions expected during a disaster, the receiver was designed to have the lowest possible noise figure. The base station weighed 13 kg. However, the motor car battery needed to power it weighed rather more at 15 kg.[13]
The portable equipment to be carried by a Proto team brigadesman was as small and light as possible within the constraints imposed by the valve technology of the time. It was intended to transmit a simple on-off code by means of a push-button because of the radio operator's inability to speak. It was believed, quite rightly, that teaching everyone the Morse code was neither feasible nor necessary as long as a simple question and answer protocol was developed between the fresh-air base radio operator and his counterpart using the portable equipment. The portable transmitter, which resulted, produced about 2 W and its receiver also had the lowest possible noise figure. The portable set weighed just over 6 kg, including batteries.[13]
Loop antennas were used at both the fresh-air base and with the portable equipment. The base station antenna, shown in Figure 3, was a 1-m diameter multi-turn loop encapsulated in fibreglass and intended to be positioned horizontally on the ground. This orientation would ensure that it had all-round coverage, unlike the long length of wire intended by Wadley, which was markedly directional. The portable set, with its multiturn loop antenna contained within the rigid carrying harness,

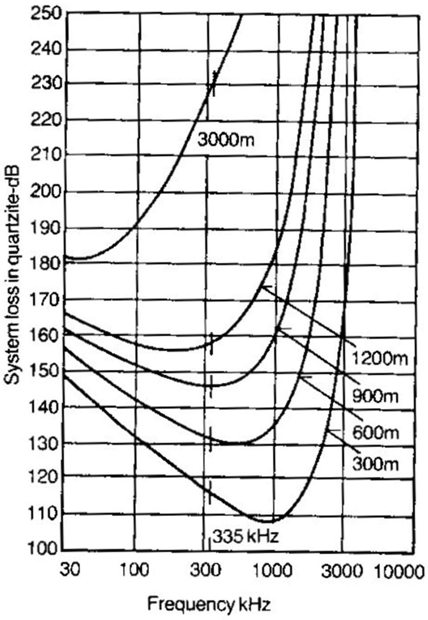

Figure 2: Calculated system loss with frequency

Figure 3: The fresh-air base radio equipment, its battery and multi-turn loop antenna.

is shown in Figure 4. The receiver's loudspeaker was mounted within the harness and positioned close to the operator's ear.

Figure 4: A brigadesman, using Proto breathing apparatus, with the portable radio equipment slung across his chest.

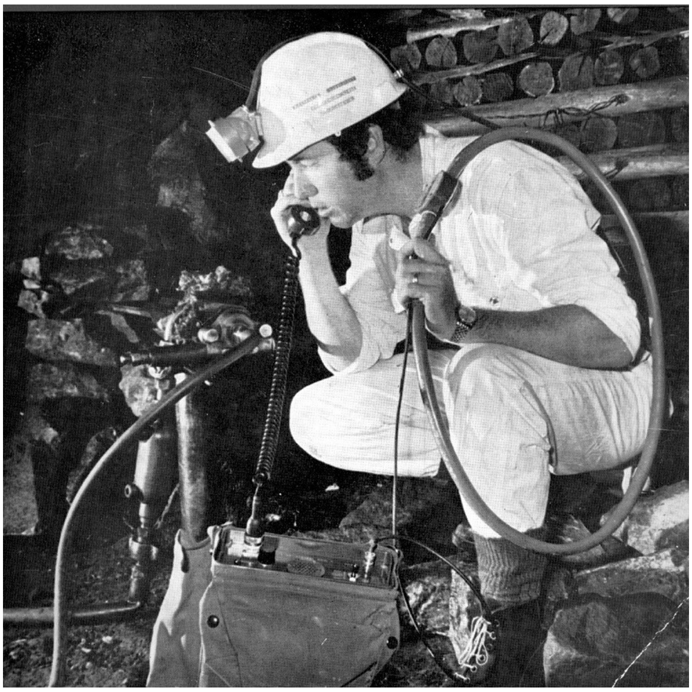

Figure 5: The single-sideband 335 kHz solid-state transceiver with its

Underground trials

Numerous underground trials were conducted by the Chamber's engineers. It soon became apparent that the communication ranges achieved were often considerably greater than those predicted by Wadley. The reason was that the signals were being conducted (and then re-radiated) by any cables, pipes and even the rails used by the electric and diesel-powered locomotives that transported men, materials and, of course, the gold-bearing rock throughout the mine.[13]

By contrast, in areas completely devoid of all conductors, communication range varied considerably, not only from mine to mine but also within a single mine. The reason, of course, was the complexity of the geology.

Extensive investigations carried out in subsequent years provided considerable insight into the propagation mechanisms involved through what was an inhomogeneous lossy dielectric medium, usually stratified and intersected by intrusions such as dykes. A most important theoretical analysis, carried out by J.R. Wait in the USA, provided the first detailed explanation of the phenomena.[14]

He showed that rock stratification can actually guide radio signals to greater distances than would be possible through a homogeneous medium. This would later be confirmed both in US coal mines and in South African gold mines.[15]

But, despite the progress made, it was clear that the equipment was too bulky and heavy.

A solid-state solution

In the late 1960s, the Chamber contracted a company in Cape Town to produce a compact, fully transistorised transceiver modelled on the packsets then coming into service with the armies around the world. Instead of a separate base station and a portable unit, a single piece of equipment could function in both roles, with the option to use a much bigger loop antenna when the equipment was set up at the fresh-air base. Single-sideband modulation instead of the AM would be used. For the same amount of transmitted power, single-sideband yields a 9 dB signalto- noise ratio advantage at the receiver. The equipment, as produced, operated at 335 kHz and is shown in Figure 5 along with its elliptical loop antenna. Being completely solid-state, it was considerably smaller and lighter than the previous valve-based hardware and contained its own rechargeable battery supply. The transmitter power output was increased to 10 W and the receiver, again, was as sensitive as possible. Once again, small multi-turn loops were used with the portable equipment with a larger, single-turn, flexible loop at the base station. Attention was also paid to ensuring that the equipment was 'intrinsically safe' so that it could be used in the flammable atmospheres typical of some mines.[16]

Once the prototypes had been evaluated and accepted by the Chamber's Electronics Division, a company in Braamfontein, Johannesburg, was commissioned, in 1972, to manufacture a small quantity for further testing by the Rescue Training Station personnel. Word had by now reached the United States Bureau of Mines (USBM) about these South African developments and they purchased six transceivers for evaluation in US coal mines.[15] Soon applications other than mining emergencies suggested themselves and the Chamber laboratories demonstrated the equipment's usefulness for complex underground activities such as raise-boring and tramming as well as within the stopes adjacent to the reef being mined. One of those special projects was the Chamber's Mining Technology Laboratory's mechanised mining programme at Doornfontein Goldmine near Carletonville. There, more than 3000 m below the surface, multiple rock-cutting machines were undergoing evaluation and assessment. It was believed that good communication between the machine operators and the maintenance personnel would improve the efficiency of the process significantly. But the extremely cramped confines of a gold mine stope made even that packset-size equipment too unwieldy and so the need arose for something even smaller.

Handheld communications

Examination of Figure 2 shows that a frequency close to 1 MHz could be used very effectively to communicate over a distance of 300 m through quartzite, with a considerable saving in transmitter power compared with 335 kHz. In addition, those experimental mechanised stopes were well

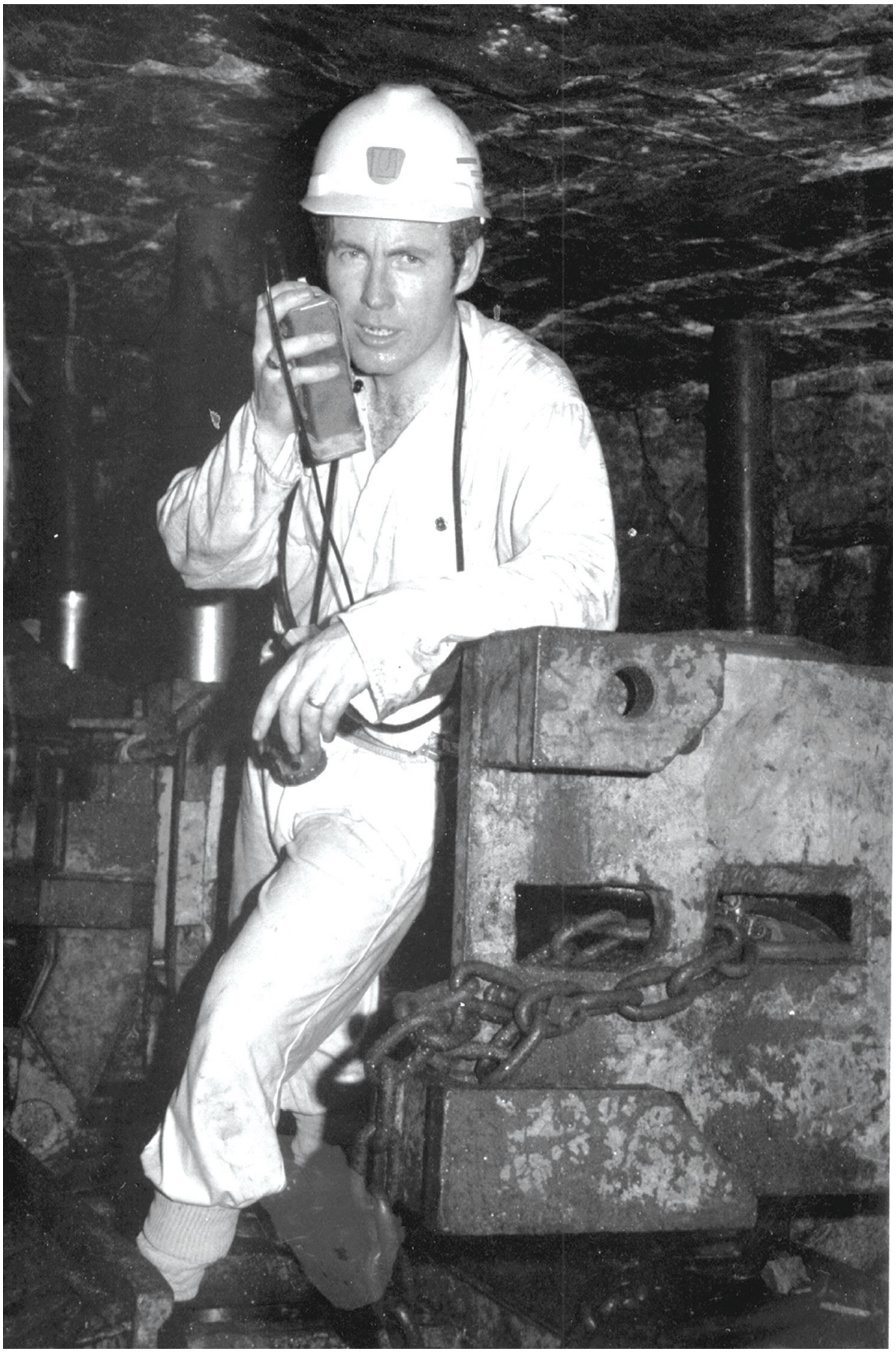

Figure 6: TXR-1 903 kHz handheld transceiver in a mechanised gold-mine stope.

served by armoured power cables and hydraulic lines. Tests had shown that this higher frequency propagated very effectively in and around the stopes, so an immediate design effort was mounted to produce a handheld transceiver.

The outcome was a single-sideband transceiver which weighed much less than a kilogram.[16] It was called the TXR-1 and operated at 903 kHz for reasons of the novel technology used (Figure 6). The transmitter output power was 1 W. The antenna was a flexible multi-turn loop that fitted, bandolier style, around the miner's body. The TXR-1 provided excellent two-way voice communications with a base station (using the same transceiver technology but with the addition of a 10-W power amplifier), plus a large loop antenna, erected in the storeroom close to the stope from where the whole operation was coordinated. More than a hundred TXR-1s in their canvas carrying pouches were produced over the following years to serve the rock-cutter stope.

Commercial opportunities

The undoubted success of the TXR-1 had indicated that a more sophisticated small radio transceiver might well find applications throughout the mining industry. With this in mind, the Electronics Division set about developing a prototype which would embody stateof- the art electronic techniques. The intention was that it should operate from 100 kHz to 1 MHz in 10-kHz steps.[17]

Multiple mining activities all within the same relatively small area, if required, could then be accommodated on adjacent frequencies. Trials underground showed the hardware to be very acceptable, and so an approach was made to a commercial manufacturer of military-grade electronics equipment in Pretoria to customise it. The outcome was that, by 1978, the SCR-100 portable and SC-200 packset transceivers were available for sale to the mining industry. They immediately went into service with the Rescue Training Station (Figure 7) and in the rock-cutter stope. An energetic marketing exercise was then mounted by the manufacturer which resulted in many mines in South Africa, elsewhere in Africa and abroad, purchasing the equipment.[17]

An underground laboratory

The part played by power cables, water pipes and even rails in enhancing signal propagation was an undoubted fact, but the mechanisms involved were poorly understood. However, research in the USA and Europe had identified two possible modes of propagation known as the monofilar and bifilar modes.[18] The details are beyond the scope of this Commentary, but suffice it to say that one or other of those modes can be used very effectively if the radio antennas are in fairly close proximity to those conductors. It was found that positioning a base station within an electrical sub-station, either underground or even on the surface, could yield really long-distance (>3000 m) radio communications by one or other of those modes.[19]

To investigate all the modes of propagation, an underground laboratory was required and a convenient site was found in a completely workedout area of a mine devoid of electrical conductors. The rock was predominantly quartzite but there was also considerable stratification both above and below the test area. It became apparent that the direction of the

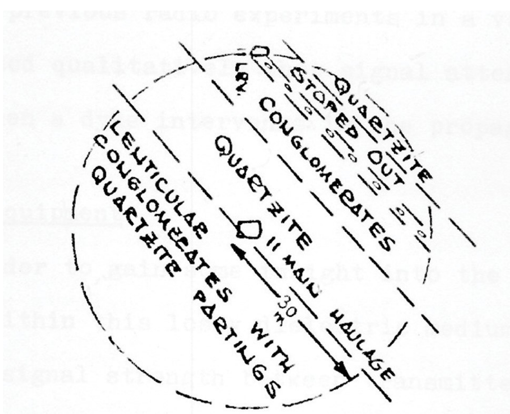

Figure 8: The geology of the rock surrounding the test

electric field polarisation affected the rate of signal attenuation. Maximum signal strength occurred when the antennas were tilted some 40 degrees to the horizontal. This implied that the strata of the surrounding rock were affecting propagation. Examination of a map (see Figure 8) showing the geology of the area confirmed that dip angle of the strata.[17,20]

To investigate conductor-assisted propagation, a single 1400-m length of copper wire was suspended from the hanging wall of the tunnel. As no other conductors were present, it was assumed that the monofilar mode might propagate with the current return path being through the surrounding rock.[18] However, measurements showed rates of attenuation that were significantly lower than were expected between 100 kHz and 1 MHz. There had to be another conducting path for the signal. It turned out that a water trough filled with mine run-off water some 500 times more conductive than tap water, and considerably more conductive than quartzite, provided the return path. An extensive set of experiments confirmed this to be the case[21], and again there was theoretical support in the literature.[22]

In summary, Figure 9 shows a composite set of curves representing all the various propagation modes discussed above. It is clear that there is general agreement between experimental and theoretical results, while the frequency dependence and complexity of all the various modes of radio propagation underground are evident.[23]

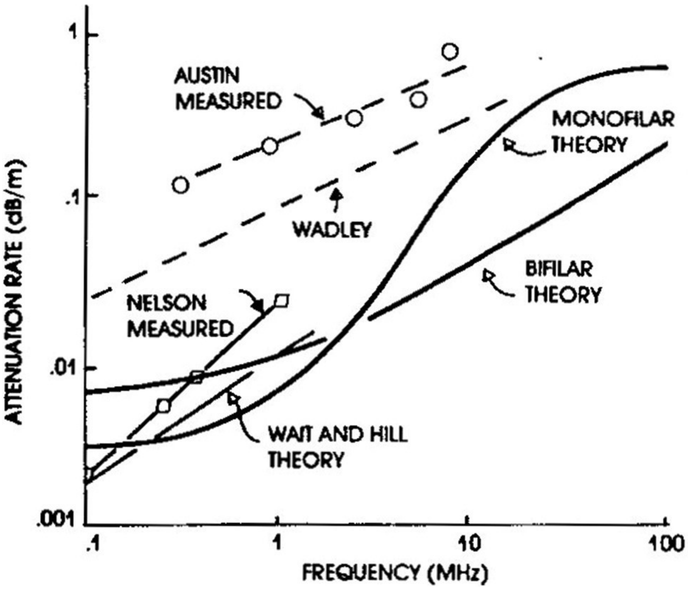

Figure 9: Comparison between theoretical and measured attenuation rates with frequency for various modes of propagation underground.

Conclusions

The work undertaken on radio communication underground in South African mines in the 50 years after the issue was first raised in 1938, has been reviewed. Significant progress was made, particularly in the design of radio equipment suited to this demanding task. Modes of propagation, both directly through the rock and indirectly via any suitable conducting paths that spanned the area between transmitter and receiver, were identified and numerical data obtained to substantiate their characteristics.

Acknowledgements

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Competing interests

I have no competing interests to declare.

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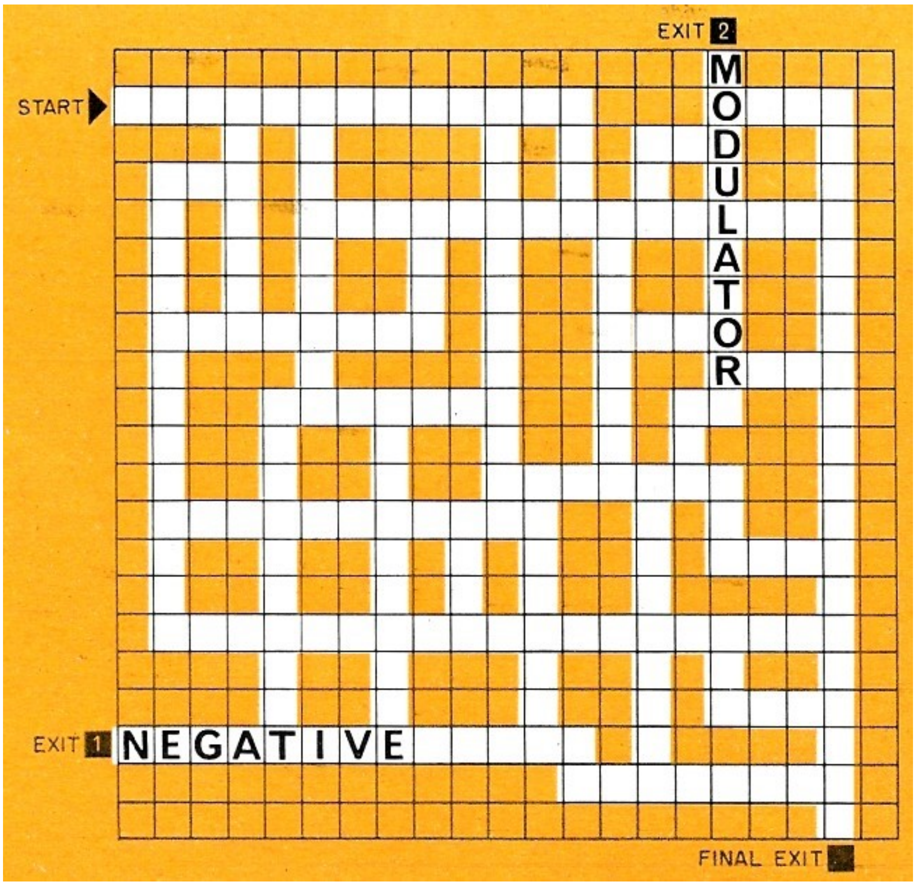
Acknowledgement to the SA Journal of Science for this article.

y Robert C. Radford

Here's a new kind of crossword puzzle designed to test your knowledge of electronic terminology. Refer to the clues given and fill in the word called for by the first clue. Start at the arrow. Thereafter, fill in each new word called for by the following clues perpendicular to each preceding word. The first or last letter in each preceding word will be common to the first or last letter of each new word, and all words will read vertically downward or from left to right. The tenth word will have a letter in common with the word at the first exit. Nine more correct entries will take you to the word at the second exit, which will also share a letter with the last of these nine words. In each case, the first or last letter of the exit word will be the first or last letter of the next word. An additional nine correct entries will put you at the final exit for a perfect score. A correct entry may or may not fill up all of the white spaces available.



Clues

1 Noise in a radio receiver, sometimes caused by atmospheric conditions.

2 Metal surface on which electronic circuits are mounted.

3 Abbreviation for the effective value of an alternating current or voltage.

4 .Instrument for electrical measurements.

5 Unit of resistance measurement.

6 Synonym for a sine-wave generator.

7 A revolvable device on which recording tape is wound.

8 Conductor used with test equipment.

9 To hinder or prevent oscillation or vibration, such as the quivering of a meter pointer.

10 One end of a bar magnet.

Exit 1. Polarity resulting from excess of electrons.

11 Voltage representing angular difference between shaft position and stator of a svnchro control transformer.

12 Series-connected coil in on electron tube plate circuit, providing feedback to grid through inductive coupling.

13 Visible form of energy.

14 Thin sheet of copper or other metal, often bonded to phenolic boards.

15 To supply a signal to the input of a circuit.

16 A doughnut-shaped coil.

17 Circuit that rejects undesired signals.

18 Wood used for making speaker enclosures.

19 Signal reflected by a distant target to a radar screen.

Exit 2. Device for mixing carrier frequency and signal frequency to produce sideband frequencies.

20 Negative or battery side of a telephone line.

21 A long, narrow channel or depression.

22 A transistor element.

23 Scientific research/development center (abbreviation).

24 Unit of length equal to one-thousandth of on inch.

25 Microwave amplification by simulated emission of radiation.

26 Undesired low-frequency vibration, usually associated with turntables.

27 May be transformed from one form to another, but usually cannot be created or destroyed.

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