Wireless on the ‘White Train”

– RADIO COMMUNICATIONS DURING THE ROYAL VISIT OF 1947

Soon after the Second World War, the most notable event occurred in South Africa. On 17 February 1947, the largest battleship in the Royal Navy, HMS Vanguard, berthed at Duncan Dock in Cape Town. Onboard was Britain's - and South Africa's - Royal Family, King George VI, his wife Queen Elizabeth and the two Princesses, Elizabeth and Margaret. They had arrived for their visit to southern Africa.

By | Dr Brian Austin

It happened because South Africa's Prime Minister, Field Marshal J.C. Smuts, had invited them. It was a visit regarded with much expectation by some South Africans, with disdain and even hostility by others and curiosity by the majority. And the King wished, personally, to thank the youngest Dominion in the British Empire for its excellent service during the World War that had come to an end less than two years before.

The Royal party would travel more than 17,000 km across South Africa and some of the surrounding British Protectorates for two months. Most of that journey took place on a specially constructed train – of quite some grandiosity - known as the White Train, in the company of two others that provided all the essentials to make the Royal Visit a success. Over the intervening 75 years, what was, ironically, to become South Africa's swansong with the British Empire has largely been forgotten for an assortment of reasons which any student of South African history (both old and new) will not find hard to discern. But that is a story that has been well-told by many writers and commentators, so it will not detain us here.

However, one aspect of that epic journey was probably almost unknown, even in 1947 when the tour was at its height, and it is undoubtedly unknown today: the story of the design, installation and operation of the unique telecommunications system that was installed in those trains. Its purpose was to guarantee the Royal party's safety and ensure the success of their visit by providing continuous communication even when on the move. As well as His Majesty's need to be in constant contact with his government back in England, there was the travelling contingent of newspaper reporters who all had deadlines to meet. None could afford to wait until the train pulled into a station to file their copy; it had to be on

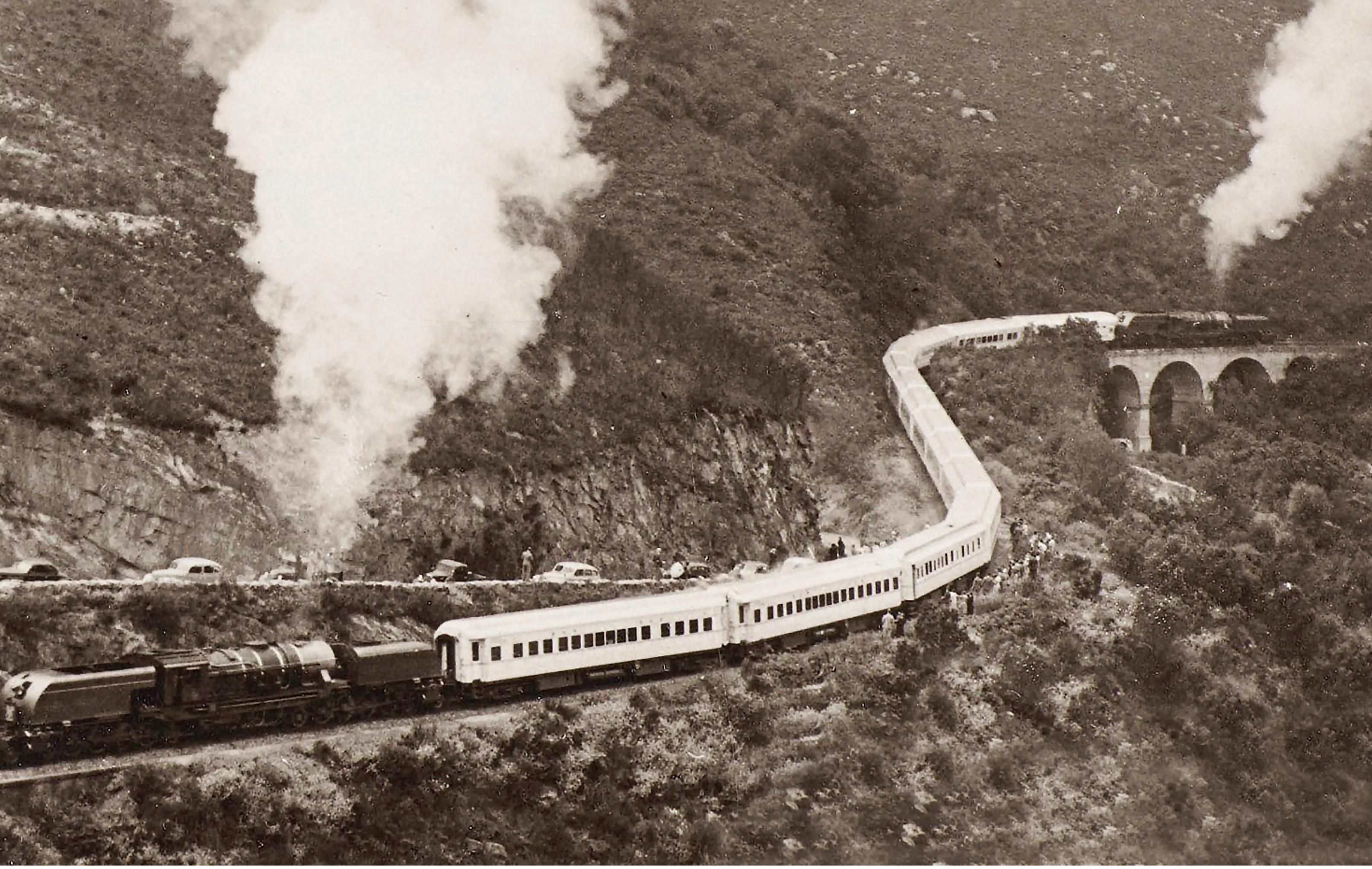

Figure 1: HMS Vanguard at anchor in Cape Town

its way to an editor, somewhere around the world, as soon as they had typed it. That telephone, telegraph and radio equipment, which only arrived from England in the first week of December 1946, was installed in the workshops of the South African Railways in Pretoria. Thankfully, for posterity's sake and the accumulation of technical knowledge, The SAIEE recorded the details of that massive engineering enterprise soon afterwards in the pages of its Transactions. And thankfully too, those bound volumes have been digitised and are available for consultation by engineering historians and other interested readers. For this, we have to thank the foresight of the SAIEE's senior officers and the dedication of its administrative staff.

I shall attempt in this article to tell that technical story with particular emphasis on the high-frequency radio communications equipment aboard the train. It provided virtually unbroken communications with Railway headquarters in Johannesburg from wherever the White Train and its accompanying rolling stock happened to be on that mammoth journey.

SOME BACKGROUND

A visit, anywhere, by British Royalty is always an event. Nothing is left to chance, and the accompanying pomp and circumstance are not only fundamental to its success. Still, they are demanded by the thousands of people who line up to watch the processions and the pageantry.

And so, this very significant Royal Visit to South Africa received not only the attention of the Lord Chamberlain in England, whose province was the heraldry and, some might say, the flummery of every occasion, but it became a momentous event in South Africa, too, involving various levels of the protocol in Pretoria some of it, seemingly, quite flummoxing. It was General Smuts (as he was always called in South Africa) who had extended the invitation to the King to visit the country with his family to have a holiday after the incredibly stressful times of the war. But a holiday it certainly did not turn out to be, much to Smuts's alarm and concern [1]. The combined officialdom in London and Pretoria made arrangements that left very little time for relaxation.

After a grand parade through the flag-bedecked streets of Cape Town and a State Banquet in the Cape Town City Hall, His Majesty the King officiated at the State Opening of Parliament. Bands played, the guns fired the Royal salute on Signal Hill, soldiers presented arms, and the South African Air Force put on as spectacular a flypast as it could muster. Cape Town was captivated though there were mutterings from some politicians who were less than well-disposed to what they saw as British imperialism on their doorstep. They believed this was an assault on their embryonic republican ideals and, as events but a year hence would reveal, those ideals had much grassroots support beyond the reaches of metropolitan South Africa. However, this was not the time for most people to show it.

The King and Queen and their two daughters Princesses Elizabeth (left) and Margaret (right) with General Smuts.

On 21 February, the Royal train, the 'White Train' as it came to be known, left Cape Town on its journey across southern Africa. The Royal Visit had begun [2].

THE TRAINS

With its fourteen carriages in their ivory and gold livery, the White Train presented an impressive sight as it travelled northwards into the heart of the country. It was preceded by another train, the Pilot train, in the relatively less startling standard chocolate brown and cream colour scheme of the South African Railways (SAR). Behind was a third train, known as the "Ghost train", because of its virtual anonymity. Each had a specific and vital role in what was to become, perhaps, the most extensive railway tour ever undertaken by royalty anywhere.

Eight air-conditioned all-steel coaches, manufactured in England, especially for the Royal Visit, accommodated the Royal Family and their immediate entourage from equerries and private secretaries to Ladies of the Wardrobe, countless other folks with specifically-designated Royal duties and, of course, the King's bodyguard, as ever a detective from Scotland Yard in felt hat and raincoat.

Among them, too, was the Minister in Attendance – a South African Cabinet Minister whose function was to provide all necessary liaison with the King on behalf of his government. This was a role that was transferred between many members of the Smuts Cabinet as the tour progressed and allowed them to operate at a somewhat different level to that required when performing their usual ministerial duties. And their wives rather relished the opportunity it afforded them for some Royal hob-nobbing.

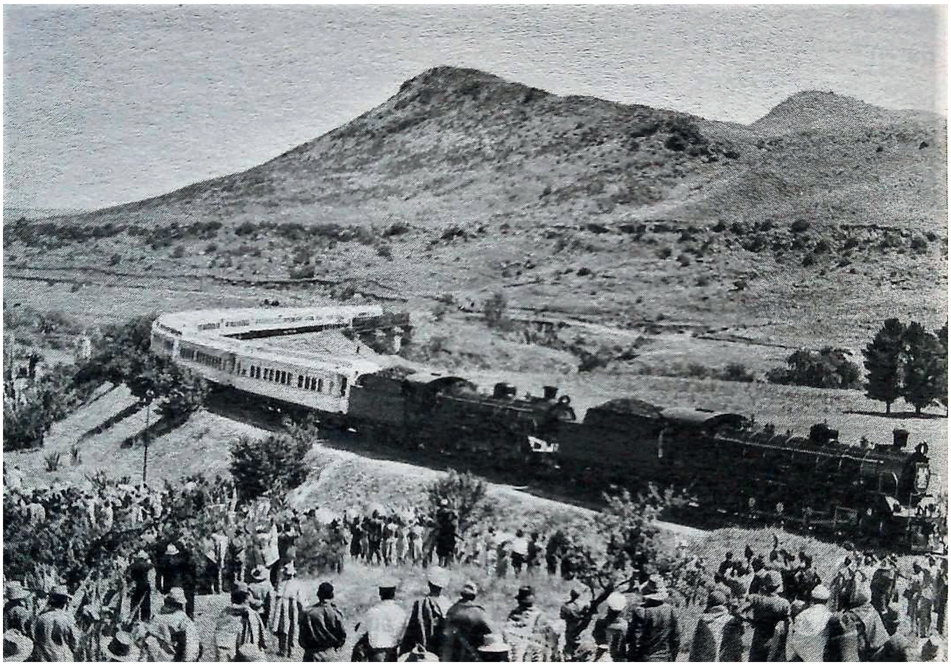

Figure 3: The White Train and a crowd of curious onlookers.

The remaining six splendid ivory and gold-hued coaches came from the SAR's luxury train, the Blue Train, mainly repainted for the occasion. For the next two months, they became the home of a seeming multitude of officials from both countries with duties to perform in direct service of the King as the tour unfolded.

Those last carriages were all of wooden construction – a crucial factor for the success of the radio communications, as will soon be revealed. Under normal circumstances, the construction of those eight steel coaches would have taken two years, but these were not normal circumstances. Smuts had committed himself to a General Election in 1948.

It was imperative, he believed, that the Royal Visit should take place well before the frequently less-than-seemly political in-fighting and, at times, outright outrightly skulduggery was unleashed on the country. British industry, along with their counterparts in South Africa, went into overdrive to deliver the necessary rolling stock in time for it to be fitted out with all the appointments required for comfort, in this extraordinary instance, for communications. The eight steel coaches were manufactured in Birmingham, with the SAR having despatched a senior electrical engineer and two draughtsmen to be involved from the outset.

The air-conditioned coaches, including the most up-to-the-minute and well-appointed dining car, were completed within nine months and arrived, by sea, in Cape Town in December 1946, a mere couple of months before the convoy of trains was to leave the city with its Royal entourage on board.

With its wooden coaches, the Pilot train made use of the usual SAR rolling stock. It too underwent a major refit at the SAR mechanical workshops in Pretoria to be able to accommodate the Administrator of the whichever Province the train was passing through and the contingent of local and overseas press and broadcasting personnel with all their paraphernalia. Should such services be needed, there was also a sizeable police contingent and medical staff. In addition, the Pilot train had its own catering and dining facilities sufficient to tend to the dietary needs of all its passengers.

The Pilot train preceded the White Train by about thirty minutes, and no other traffic was permitted on the line between them [2].

Each train had its own train manager with duties similar to those of the captain of a ship. He was responsible for the safe running and operation of his train and particularly the safety of his passengers. Upfront, on the footplate of the engine (of which the White Train always had two locomotives), in addition to the driver and the fireman was a locomotive inspector, a senior and very experienced driver charged with monitoring every aspect of the operation of those locomotives throughout the tour. Bringing up the rear was the Ghost train to transport any spare parts that may have been needed and the skilled mechanics and technicians to effect any such repairs.

Throughout the tour, the trains travelled only by day. At night the White Train was taken to a quiet station or siding remote from any towns or villages. This was all done in the interests of safety and security. In the larger centres where the King was to perform some function and meet local dignitaries (as well as ordinary folk) over a more extended period of two or three days, the Royal party and their staff were taken to an official residence set aside for their sole use. The arranging and coordinating of all these necessary actions by the various senior officials travelling on the White Train, and its all-so-important Pilot train, required good inter-communication between them at all times, even when they might be as much as 40 km apart [2]. That required radio. The press corps, meanwhile, had a copy to file, and it too had to reach an editor's desk well ahead of the

Figure 4: The Royal Family alights from the White Train somewhere.

tight deadlines of the newspaper and broadcasting industries. The reporters required radio communications to do that when on the move, but they wanted instant access to South Africa's telephone and telegraphic networks as soon as the trains came to a halt for more than a few minutes at any station anywhere. And unsurprisingly, the Royal party and their entourage had their own needs for such telecommunications services. So the South African Railways and the Post Office set out to provide them.

TELECOMMUNICATIONS TRIUMPH

As mentioned above, we have to pay tribute to the Transactions of the SAIEE (and, naturally, to the authors concerned) for providing such a complete and very detailed account of the telecommunications facilities built into both trains. Without the paper by Manson [3], a senior SAR engineer, this account would have been sparse in detail. In England and South Africa, the engineers' problems were undoubtedly not routine.

Several various items of equipment had to be accommodated in minimal space, and, where necessary, all the cabling linking them had to be laid as inconspicuously as possible. With remarkable foresight, undoubtedly based on years of experience, attention was given from the very beginning to the likelihood of interference occurring between those various systems.

Though such problems had plagued electrical communications systems since man first used the electric telegraph, understanding the mechanisms and the devising of methods to mitigate them had not yet been given a name. Today it is known as electromagnetic compatibility (EMC). A British company specialising in the field was contracted to solve all such problems as and when they arose during the installation phase of this most complicated process.

Another major item requiring attention was the power supply needed to keep all the equipment functioning. All communications equipment was to run off 220-volt 50 Hz. As soon emerged, the bulk of the communications hardware, both wired and wireless, would be placed within the Pilot train, and the power requirements were beyond the capabilities of the battery supply. A suitable prime mover and alternator were therefore required. In addition, to supplement it, a 2.5 kVA motor alternator set, operating off the train's 24-volt lighting batteries, was also provided. A similar set was all that could be accommodated on the White Train, except that in this case, all the equipment would operate off 65-volts d.c.

The most important of those items were for the entertainment of the passengers. Broadcast receivers were installed in the many lounges. At the same time, three specially-sprung radiograms that would function with the 78 rpm records of the day without, literally, missing a beat regardless of the undulations of the track and the attendant movements of the train were carefully positioned for those even inclined to dance.

The conventional broadcast receiver in His Majesty's private study was particularly important. Its quality of reproduction was to be beyond reproach! As laid down in the specification, it had to have 'good sensitivity and selectivity plus ample band-spread over the primary medium and shortwave bands.

The specifications for all the hardware were completed in April 1946, and they were passed to five British firms contracted to manufacture it. This was a mere nine months before the start of the Royal tour. Unfortunately, no doubt governed by the Institute's policy on advertising at the time, the names of those companies were never mentioned.

Still, it is reasonably easy to guess who they might have been given the prominence of the Marconi Company, Metropolitan Vickers, AEI, GEC and Reyrolle Parsons within British engineering in those days. The closest collaboration existed between them and engineers within the SAR and the South African Postal Administration. Given the rather specialised nature of some of that equipment, there was a need for a degree of research and development. And all had to be carried out under the tightest of time constraints.

THE AUTOMATIC TELEPHONE SYSTEM

All compartments on both trains were served by a telephone, the standard black BPO type for the entourage accompanying the King but a cream-coloured instrument for each Royal party. The telephone exchanges had a capacity for 68 lines, allowing automatic access to any subscriber on either train when they were interconnected. The full-extension was possible to both the SAR telephone network and the Post Office at each port of call along the route. This all went via a switchboard operator.

The "cut in on engaged" feature provided only for privileged subscribers was a curious but perhaps not surprising facility. One can well imagine who they might have been. Its operation was described thus: 'On receiving the busy tone after dialling the desired number, the subscriber would dial "0", which gave him (sic) access to the engaged circuit. The other subscribers would be informed of this intrusion by simultaneously applying a "ticking" secrecy tone to the circuit. They would then be requested to replace their handsets.' The operator at the exchange had a similar feature that made such "cut-in" possible to interrupt any conversion on receipt of a trunk call. This was no egalitarian party-line service!

The network was interconnected by a 75-pair cable running the length of each coach. Whenever the two trains were stationary for any significant period, both exchanges were linked by two tie lines. As mentioned earlier, meticulous attention was paid to the screening and filtering associated with those cables to ensure that no interference was carried along with the wanted signals.

Careful attention was also given to providing telephone communications between the respective train managers and the crew of the leading locomotive of each train. In those cases, electrical noise was not so much the problem, but the extremely high acoustic noise level was. It too was solved by using army-type loud-speaking telephones and their accompanying "power microphones", all appropriately accommodated on the footplate.

THE RADIO LINK BETWEEN THE TRAINS

For an assortment of reasons, it was necessary that the two trains were to be in radio contact throughout their journey across the country. The all-steel construction of the White Train provided many problems in this regard. In contrast, the wooden coaches of the Pilot train certainly made life a little easier for the radio engineers. In both instances, however, the placement of the appropriate antennas posed problems owing to the height of the coaches relative to the height of the tunnels which they would have to pass through en-route and, particularly, in those areas where overhead catenary wires electrified the lines. The solution to the possible noise problems from those overhead lines was to use VHF transmitters with 10 W output and frequency modulation.

The SAR engineers favoured a frequency around 150 MHz (or Mc/s as it was in those days), but their British counterparts were concerned about the alleged "optical" effects at the short wavelength. This was a strange but persistent fear among British radio engineers and physicists that had its roots lodged in wartime thinking. The Battle of Arnhem in September 1944 was a calamity for the British Army for many reasons, one of which was the inadequacy of the radio communications between its troops. British military radio doctrine at that time saw VHF as being effective over a very short-range (i.e. a few miles) because, as was claimed, 'such frequencies propagate only in straight

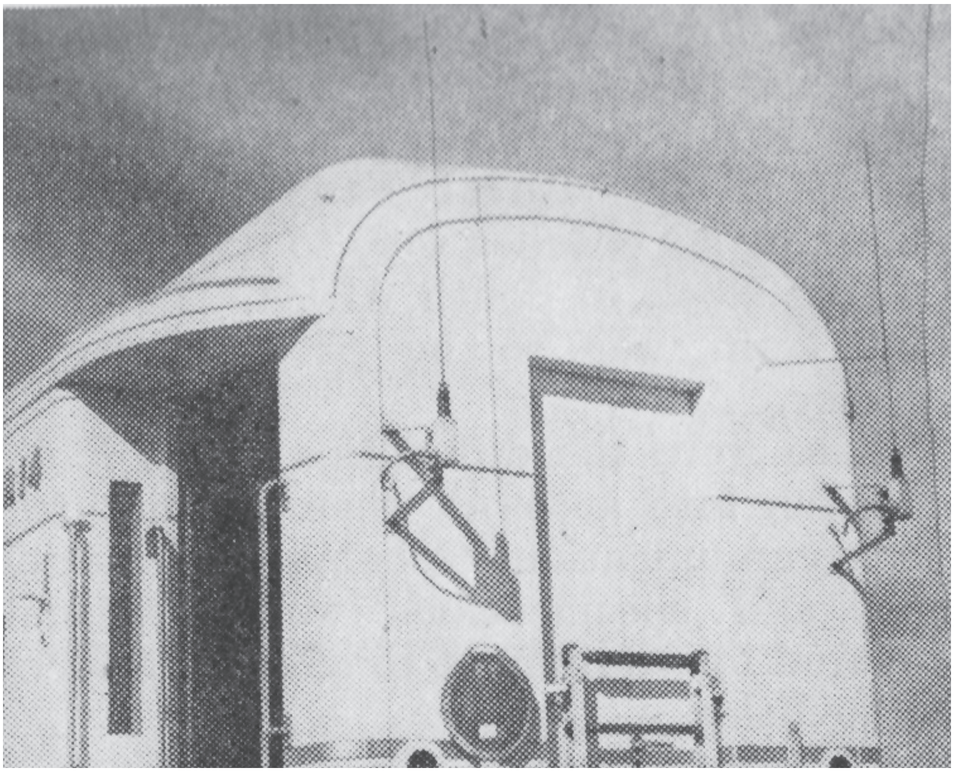

Figure 5: The extended VHF antennas on the White Train [3].

lines, old boy.' The army, therefore, used frequencies in the low MHz range, which propagated (equally poorly, as it turned out) via the ground wave. In addition, the much under-powered manpack equipment on a soldier's back used an antenna no more than two metres long. Any longer, and the unfortunate radio operator became a much sort-after target. Such short antennas were, as expected, highly inefficient radiators.

Therefore, a frequency of 80 MHz was felt to be more appropriate for distances up to the expected 40 km that could occasionally separate the two trains. That immediately meant antennas twice as long as the SAR had intended. However, a vertical quarter-wavelength whip mounted on a flexible base on the coach roof would pass through all tunnels without any difficulty. Likewise, it would be sufficiently below the overhead power lines for there to be no concern. But to be absolutely sure that this inter-train VHF never failed, two additional and somewhat longer antennas – yielding slightly more gain - were mounted at the rear of the White Train. As it transpired, the short roof-mounted antennas proved to be more than adequate throughout the journey.

LONG-DISTANCE HIGH-FREQUENCY RADIO COMMUNICATIONS

Given the vital need to protect the safety and security of the Royal party throughout their very long rail journey across southern Africa, it was a pre-requisite of all the planning that went on that the White Train should be in radio communications with one or more key SAR centres at all times. In addition, the King himself had to be kept abreast of developments on the wider international stage, should the need arise. This necessitated his being in radio contact, ultimately, with London. And then there were the other government officials travelling with him and a veritable posse of journalists. They all needed such communications facilities to carry out their duties, and only radio could achieve that. It fell, therefore, to the joint efforts of the SAR and Post Office engineers, working in very close collaboration with their British counterparts, to provide it.

In those pre-satellite days, the only means of communicating over hundreds and even thousands of kilometres was high-frequency HF (or shortwave, as it was known) radio. Given the nature of the ionosphere on which such communications depend with its variability by day, by season and by the vicissitudes of the sunspot cycle, several different radio frequencies spread across the 3 to 30 MHz HF band would be required. Such allocations were in the gift of the Post Office, and five frequencies lying between 4 and 11 MHz were allocated to the Royal trains.

As it perhaps unsurprisingly transpired, the SAR already had a sophisticated radio network across South Africa since it too needed communications over and above those provided by its own telegraph lines and those of the Post Office. This had been precipitated at the outbreak of war in 1939 by divisions within the country between those supporting the Smuts government's decision to join the Allies in their war against the Nazis and those vehemently opposed to it. Among the latter group was the Ossewabrandwag, which intended to disrupt the South African war effort by all possible means. Sabotage and the destruction of telecommunication services were among the numerous anti-war measures they deployed. The SAR radio stations that soon came into being were located in Johannesburg, Cape Town, Durban, Bloemfontein, Port Elizabeth, Kimberley, Kroonstad and Windhoek.

The most crucial radio link from the Royal train was that to Railway Headquarters in Johannesburg. They had to ensure

Figure 6: The Marconi CR-100 HF communications receiver used on the Pilot train and at Roberts Heights.

that it functioned flawlessly, particularly when sending high-speed press traffic under indifferent propagation conditions. Use was made of the Post Office radio station at Roberts Heights (actually renamed Voortrekkerhoogte in 1938 and more recently Thaba Tshwane). From there, a landline completed the circuit to Johannesburg.

At 'The Heights', a triple-diversity scheme involving three Marconi CR-100 communications receivers of the same type as fitted on the train but fed from a single local oscillator to ensure absolute frequency commonality was used in conjunction with three widely separated receiving antennas to increase the spatial diversity between the received signals. This means any fading could be compensated for by combining all the receiver outputs. No stone was being left unturned.

The proximity of an antenna to a conducting structure significantly affects its performance. As emphasised above, the White Train was of all-steel construction. Though steel offered undoubted advantages compared to wood in a mechanical sense, any metallic conductor would be most disadvantageous from an electromagnetic point of view when it came to the siting of antennas, and never more so than at HF.

This problem was mitigated by placing the HF transmitter and receiver in the Pilot train with its wooden coaches. Still, their length of about 28 m would impose constraints on the antenna's maximum length, which should have been close to half a wavelength at the lowest frequency. Since the lowest frequency allocated to this vital mission was 4.055 MHz, the wavelength was about 74 m, making this impossible. Once again, an engineering compromise had to be made. But there was another factor too. Only a single (and relatively simple) antenna could be accommodated on a railway coach. Yet, the range of frequencies that would have to be used to cope with the changes in the ionosphere over 24 hours meant that the antenna had to have a wide bandwidth. No simple antenna structure possesses this feature. It had to be mounted on top of a railway coach and therefore relatively close to the ground. Its height above the coach roof was also severely constrained by the limitations imposed by any tunnels or power lines en route.

THE HF TRANSMITTER

The transmitter with its diesel engine and alternator, plus the necessary switch-gear, were located in two separate compartments of the Pilot train. The associated receiver and the high-speed telegraphic equipment went into two compartments in an adjacent coach. In addition, there was a particular cypher office on the train whose purpose was to handle any highly confidential radio traffic, usually intended for the King. It contained two "Typex" machines of the type made famous during the war just past when they were used to encipher all classified British military traffic. Unlike its German counterpart, the much-described Enigma machine, the messages from the "Typex" machine were never broken.

The separation that could be achieved between the transmitting and receiving antennas was of much technical importance. This turned out to be about 76 m, limited by the coaches' length. Since they would be approximately end-on to one another, the mutual coupling was reduced. This was all to the good since "paralysis" of the receiver when the transmitter was operated to be avoided at all costs. The transmitter produced an output power of 500 W under continuous wave conditions and half that when used for telephony in the form of amplitude modulation. Both the transmitter and receiver could be operated either locally or remotely, with the normal operation being under the operator's control at the receiver. A duplicate facility existed at the transmitter. When operating in telegraphic mode, the keying system of the transmitter allowed for traffic transfer of up to 200 words per minute [3]. Under normal circumstances, the coupling to the antenna of the transmitter dual tetrode power amplifier valves, operating in parallel, was using a two-wire transmission line with a characteristic impedance of 600 ohms. However, as a further example of the belt-and-braces approach adopted everywhere, the transmitter could also drive single wire antennas of either low or high impedance had the need arisen. The complete transmitter installation comprised a two-bay cabinet standing some 2m in height, a metre wide and 700 mm deep. The whole assembly weighed about 360 kg.

WALKER'S CRUCIAL BROADBAND ANTENNA

It is no mean feat to produce an antenna that operates over a bandwidth of more than two octaves. And the problem is made even more challenging when that antenna has to be accommodated on the roof of a train that is underway. Though he had no clue about the Royal visit to South Africa when he first looked at this problem, G. D. Walker, a lecturer at the Witwatersrand Technical College, had some experience with wideband antennas due to the research he had been doing into the development of an ionosonde. The difficulties of war and the need for highly skilled people in specific key posts saw Walker transferred, early in 1940, to the department of the SAR's Chief Electrical Engineer in Johannesburg, where he was given responsibility for all the SAR's radio communications. Walker was no neophyte in this field. Some years before, he had designed and constructed the first ionosonde in South Africa when such instruments for measuring the features of the ionosphere were not to be found

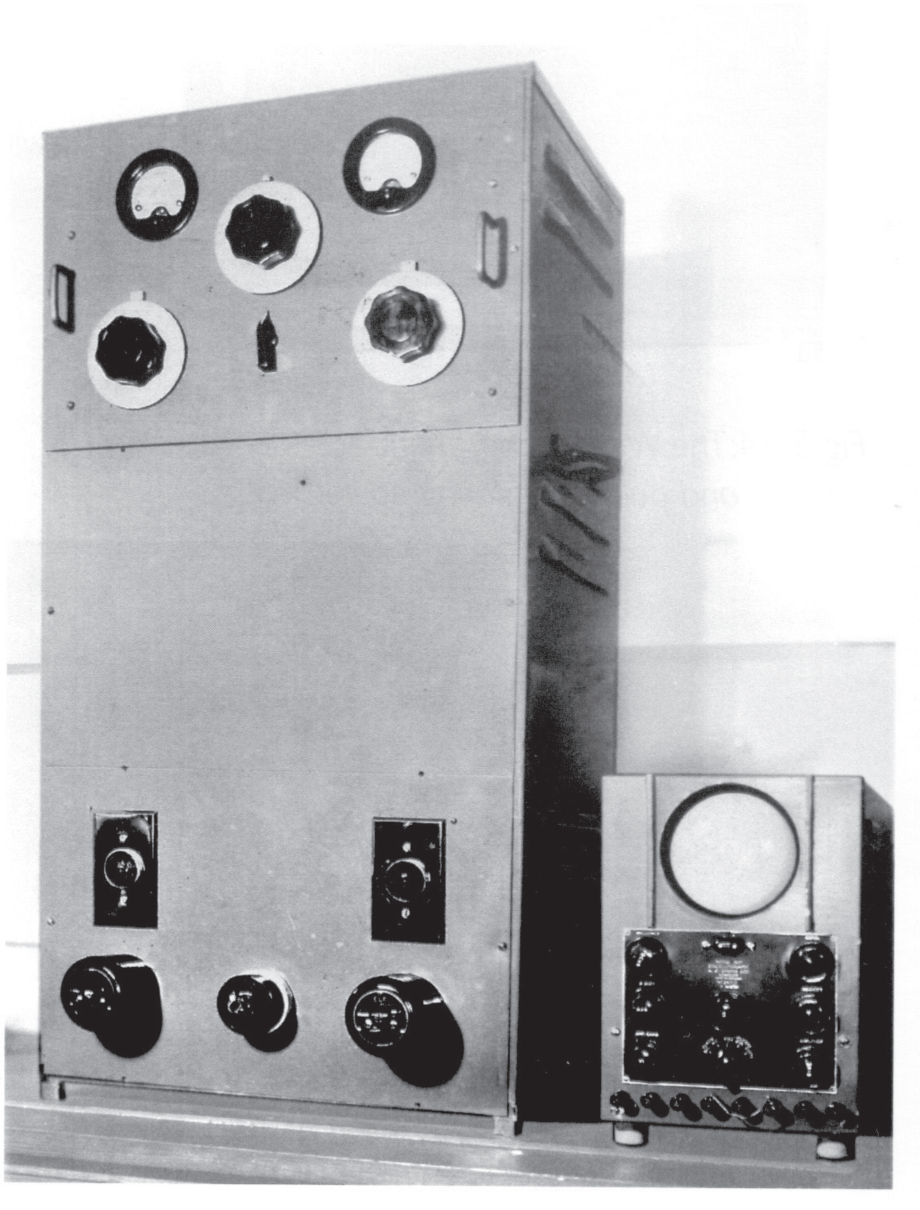

Figure 7: G.D. Walker's ionosonde that observed the effects of the solar eclipse in 1940.

in too many other parts of the world [4]. Its first use in anger, as it were, had been planned some while before when Professor B.F.J. Schonland's Institute of geophysical research at Wits intended to observe the forthcoming total eclipse of the sun by all means possible. One of those was measuring its effects on the ionosphere, and Walker's ionosonde was just the instrument. And so, in October 1940, the ionosonde was deployed at Middleburg in the Cape to record any changes in those ionised regions up above as the sun was eclipsed by the moon [5,6]. Since an ionosonde uses swept-frequency radar techniques to measure the virtual height and critical frequencies of all the ionosphere layers, Walker was well-acquainted with the problems of radiating and receiving radio signals over the 30 MHz of the HF band.

In 1946 Walker published a comprehensive paper in the Transactions of the Institute in which he described the work carried out under his direction by the SAR [7]. An essential aspect of it was the type of antenna to be used at all those SAR radio communications centres. He examined and experimented with many. Since the HF radio spectrum is vast, and antennas, in general, are narrowband devices, Walker thought, initially, that some combination of dipole elements might offer a multiband capability with resonance at the specific frequencies allocated by the Post Office to that SAR radio network. However, it turned out to be a tall order because the antennas were sizeable structures. Naturally, he discussed the problem with his academic and industrial colleagues, and a suggestion of a single element antenna that might suffice was forthcoming from England. The antenna is shown in Figure 8 with the dimensions intended for use at the various SAR radio stations across the country.

Essentially, the antenna is a folded dipole with resistive loading. An unloaded antenna of that type has a bandwidth of just a few hundred kilohertz and is similar to a high-Q resonant circuit. Any added resistance will decrease the Q and increase the bandwidth - but it comes as a cost. The antenna's radiation efficiency is reduced, so there is the inevitable trade-off between bandwidth and efficiency. Walker discussed this in detail in his paper and presented measured results showing the antenna's input impedance across the HF frequency range.

He also measured the power dissipated in the loading resistor, and, from those data, he was able to get some idea of the resulting radiation efficiency. Modern antenna analysis software enables us to do this with considerably higher precision. The results show the increasing efficiency with frequency, as expected, and with numerical values similar to those that Walker had measured. However, Walker's test antenna was nearly 20m above the ground, whereas the antenna on the roof of the Pilot train would be only a few

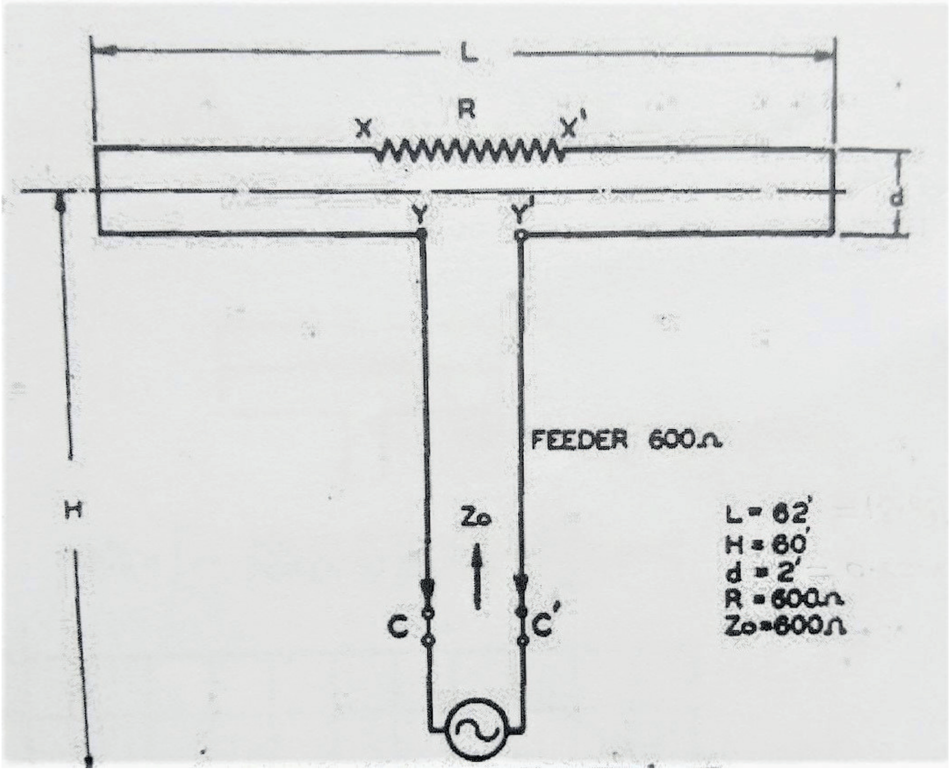

Figure 8: The resistively-loaded folded dipole antenna

metres above terra firma. The additional ground losses would inevitably degrade the radiation efficiency further. But there were no other options, so this terminated folder dipole, as it became known, was the antenna of choice for the Royal train.

THE ANTENNA ATOP THE PILOT TRAIN

Space was limited. The size of the coach determined the antenna's dimensions, so the eventual length was just over 17m. The folded dipole was made of two 12 mm diameter nickel-plated copper rods – the nickel coating presumably prevents the copper from oxidising and thereby increases its losses. The two parallel elements of the dipole were 127 mm apart, with the whole structure being supported on porcelain stand-off insulators 150 mm above the coach's wooden roof. The terminating resistor, which had to be non-inductive, thus making a wire-wound resistor out of the question, consisted of six two 000-ohm carbon bar elements in parallel held in special clips inside the coach to protect them from the weather. The 600-ohm characteristic impedance balanced feeder from the transmitter left the coach at the same point.

Leaving nothing to chance, provision was also made to deploy a longer 24m antenna whenever the train was stationary for any reasonable length of time. Being longer and higher, though also resistively loaded, that antenna would have produced a stronger radiated signal. As it turned out, it was never needed. It was held aloft by two portable 10m masts of three sections, which could be erected quickly. A computer simulation of the train antenna's height of 3.7 m above the ground yielded adequate isotropic radiated power (EIRP) ranging from 4 to 11 MHz. Given the very short antenna length, when expressed in units of wavelength, at the lowest allocated frequency of 4.055 MHz, the EIRP was just 6.3 W. By contrast, at the highest frequency of 11.4 MHz, where the longer antenna had considerably more gain, it was as high as 740 W. Though vastly different, the EIRP is not the sole determinant of successful radio communications at HF. The ionosphere has the final say, but given its variability with the time of day, the seasons and the sunspot cycle require careful frequency selection by the operators. It is, after all, the EIRP and the noise level at the receiver which together determine the signal-to-noise ratio. To give them as many options as possible, the frequencies allocated and the two mentioned above also included 5.70, 7.52 and 8.80 MHz.

Based on his previous experience when experimenting with that antenna, Walker was confident that the set-up aboard the Pilot train would prove to be effective. However, the initial tests between Pretoria and Johannesburg proved highly unsatisfactory: signals were weak on some channels and non-existent on others. But further tests with Bloemfontein were far more successful. An explanation for this follows.

Two possible modes exist: HF radiated signals could propagate over the roughly 50 km distance between Pretoria and Johannesburg. The first is the ground wave, where the electromagnetic energy literally hugs the ground's surface as it travels away from the transmitting antenna. The other is the skywave which leaves the antenna at an oblique angle where it then encounters the ionosphere and may be reflected by one or other layers.

The radiating signal must be vertically-polarised for the ground wave to propagate over a reasonable distance. Since the antenna on the train was in a horizontal position, it radiated a horizontally polarised wave, so the ground wave was virtually non-existent. This left just the skywave. Figure 9 shows Walker's 1946 paper [7] diagram illustrating this particular case. It is somewhat over-elaborate in that it is most unlikely that so many different modes would exist over that relatively short Johannesburg to Durban path that he used as an example. The ionosphere would, most likely, support just modes 1 or 2 (and then seldom simultaneously).

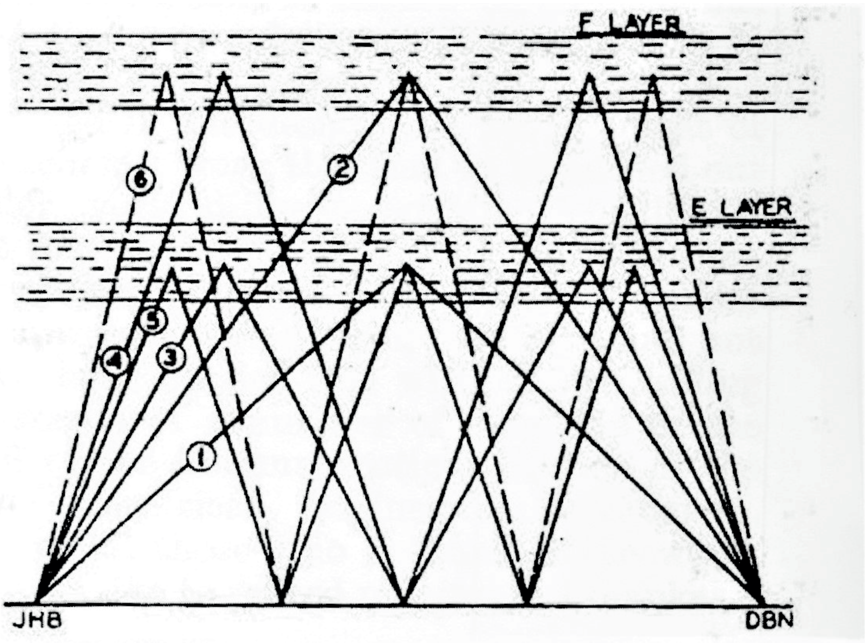

Figure 9: A stylised diagrammatic view of ionospheric propagation.

At night, for example, the E layer disappears, while it may actually be dominant around midday. Most of the time, except possibly over reasonably short distances, propagation would have been via the F layer. It will be noted that there is a region between the transmitter and the point at which the reflected signal returns to earth in which there is no radio coverage. This is known as the skip zone for obvious reasons. Over the relatively short distance between Johannesburg and Pretoria (illustrated, perhaps, by rays 5 and 6), there is every likelihood that the down-coming ray only returns to earth in Vereeniging when the train in Pretoria was transmitting and in Polokwane when the headquarters station in Joburg was doing so! Thus, the two stations were within the skip zone, so no contact between them would have been possible, hence the dismay in Pretoria when the first test failed!

IONOSPHERIC PROPAGATION PREDICTIONS

Immediately after the end of the Second World War, Schonland founded the CSIR at the behest of General Smuts [6]. One of the first laboratories to be established was the Telecommunications Research Laboratory (TRL), initially based at Wits, and the majority of its engineers and scientists had been members of Schonland's wartime Special Signals Services (SSS) that had designed, constructed and operated South Africa's own radar system throughout the war.

The first director of the TRL, which subsequently underwent a name change and became the National Institute for Telecommunications Research (NITR), was F.J. Hewitt. From its inception, a vital member of the TRL was T.L. Wadley, the designer of some truly remarkable pieces of electronic equipment [6, 9, 10]. One of the areas in which the TRL immediately became involved, and Wadley played a most significant part, was a study of the ionosphere. It was Wadley who designed and constructed the ionosonde they used.

Figure 10: The TRL (NITR) staff c.1963. F.J. Hewitt in the centre of the front row; his sister Joyce is on the far left and T.L. Wadley is on Hewitt's immediate left.

Hewitt's sister, Joyce Hewitt, became the first ionospheric physicist at the TRL, and she specialised in predicting how the ionosphere would behave some short time in the future. Doing this required daily measurements of the critical frequencies and virtual heights of those ionospheric layers, which were provided by Wadley's ionosonde [8]. Figure 11 shows an ionogram displayed on the equipment in 1947 when that particular sunspot cycle reached its peak. The horizontal axis is marked in 1 MHz intervals, while the vertical axis displays the virtual heights of the layers in 50 km steps, with the lowest interval being an altitude of 50 km. The two ionograms show the almost untouched nature of the ionosphere twenty minutes apart as measured directly above Johannesburg on an indicated day of the year. From those displays, the critical frequencies when the trace turns sharply upwards, and their virtual heights, when they are approximately horizontal, can readily be measured and used in the predictive scheme implemented by Miss Hewitt.

HOW WELL DID IT ALL WORK?

On 4 February 1947, the two trains, now fully fitted with all their home comforts and the various items of technical equipment needed so that the Royal party and their entourage, plus all the attendant press corps, could be in constant contact with the world outside, left Pretoria for Cape Town. Before setting out, routine tests were carried out with all the automatic telephone equipment connected to the national telephone network, and the few faults that were found were immediately rectified. Other more persistent problems were worked on and solved during the journey south. Radio tests commenced almost immediately after departure. A schedule of calls every half hour was agreed with the Post Office station at Roberts Heights and with all the SAR radio stations around the country. It was reported that the Reef electrification system did not affect radio communications. Manson also reported that tests continued all the way to Cape Town, and 'at no time was contact with the fixed stations lost. By judicious choice of operating frequencies for different times of the day and night, the signals were in most cases at a high level.' Not only would that have been decidedly reassuring to the SAR and GPO engineers who had played such a crucial part in all of this but, equally, it was a clear vindication of the choice of the compromised broadband antenna occupying its sheltered position on the roof of coach R27 of the Pilot train.

Once the Royal tour had commenced, Manson subsequently reported that the HF radio installation was soon hard at work with the Post Office staff handling all the radio traffic. At the same time, the two trains maintained almost unbroken contact via the VHF radio link between them, such as the demand. Daily out-going traffic in telegrams and press reports, sent to the Pilot train and thence onward to the receiving station at Roberts Heights, averaged 25 000 words per day. And as soon as the trains came to a standstill, the connection was immediately made to the landline network, with the railway telegraphists becoming telephonists to route all the calls through their two switchboards. Naturally, when within tunnels and in mountainous areas of the country, there were the inevitable VHF dead spots, but these had been foreseen, and none persisted for longer than expected. In certain parts of the country, most notably between Nelspruit and Pretoria, between Mafeking and Bulawayo and between Victoria Falls and Livingstone, communications between the trains were excellent.

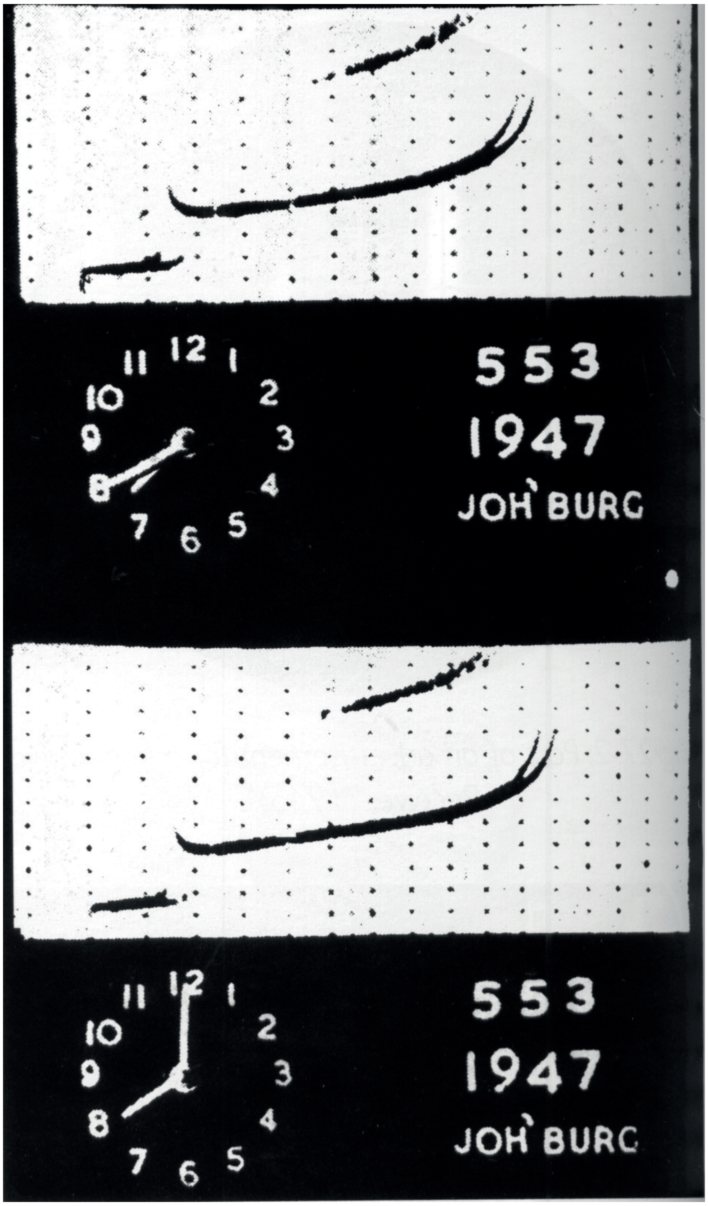

Figure 11: Two ionograms produced by the Wadley ionosonde in 1947.

IN CONCLUSION

The Royal Visit to South Africa was an unqualified success, at least in terms of its planning, the arrangements and the superhuman efforts of all who contributed so much to every aspect of the grand tour. Though usually somewhat side-lined in popular accounts and even in terse official documents, the success of the down-to-earth engineering that made so much of it possible and, most notably, the Royal trains' flawless performance cannot be overstated. In closing, Manson summed it all up as follows. 'As far as is known, communications on this scale have never before been applied to trains anywhere in the world ...' [3].

This unique event would, within a year, come to be seen as possibly the final days of South Africa's very close association with Britain, its monarchy and ultimately its Empire and Commonwealth. Local politics were changing, and a very different way of viewing the world-at-large would soon become the new government's policy. That 1947 Royal Visit was a pivotal event in more ways than one. wn

ACKNOWLEDGEMENTS

South Africa's very proud engineering heritage owes much to men of their calibre and, most importantly, to journals such as the Transactions of the SAIEE for publishing, in full and very precise detail, this material that reflects so well on those men who carried it out. Without the foresight and dedication of those engineers who took it upon themselves to write detailed accounts of the communications systems on both the Royal trains and also about all the preparatory work that went into it, we, many years later, would never have known the fascinating details. I, therefore, wish to acknowledge them and pay tribute to their work. I also wish to pay tribute to Graham Viney [2] for telling such a fascinating story about the Royal Visit and all its many niche events that so captured the South Africa of all those years ago. In addition, I must thank Gerda Geyer, at the SAIEE's head office in Johannesburg, for the considerable assistance given to me when I was pulling this article together. There are also two books, relatively recently published by the SAIEE, which provide a wealth of detail relevant to this story – and to very much more besides. Both are comprehensive accounts of the history of the Institute and electrical engineering in South Africa [9,10].

REFERENCES

1. J.C. Smuts, "Jan Christian Smuts", Cassell, London, 1952, p.502.
2. G. Viney, "The Last Hurrah – The 1947 Royal Tour of South Africa and the End of Empire", Little Brown, London, 2020.
3. M.W. Manson, 'Railway Communications for the Royal Tour', Trans. SAIEE, vol.38, pt.11, Nov.1947
4. G.D. Walker, 'A Contribution to the Study of the Ionosphere', Trans. SAIEE, vol.34, pt.3, May 1943.
5. A.C. Brown (ed.), A History of Scientific Endeavour in South Africa, Royal Society of South Africa, 1977.
6. B.A Austin, Schonland – Scientist and Soldier, IOP Publishing and Wits University Press, 2001.
7. G.D. Walker, 'The Development of a Radio Communication Network for the South African Railways', Trans. SAIEE, vol.37, pt.12, December 1946.
8. F.J. Hewitt, (Miss) J. Hewitt and T.L. Wadley,' A Frequency prediction Service for Southern Africa', Trans. SAIEE, vol.38, pt.7, July 1947.
9. M.A. Crouch (ed.), The First Ten Decades – The History of the SAIEE 1909-2009", CvR Publications, 2009.
10. D.J. Vermeulen (ed.), A History of Electrical Engineering in South Africa, vol.1, SAIEE 2017.