Telstar 1, the first active, direct relay communications satellite

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In May 2011, whilst staying with my wife's family at Guingamp in Brittany, France I visited a museum, designed by France Telecom, in the nearby village of Pleumeur-Bodou. This small museum, which opened in 1991, is extremely popular and welcomes more than 100,000 visitors per annum.

The location of the museum was the exact site where, on 11th July 1962, French engineers and technicians were waiting for the passage of the Telstar satellite which was about to relay the first live television broadcast from across the Atlantic Ocean.

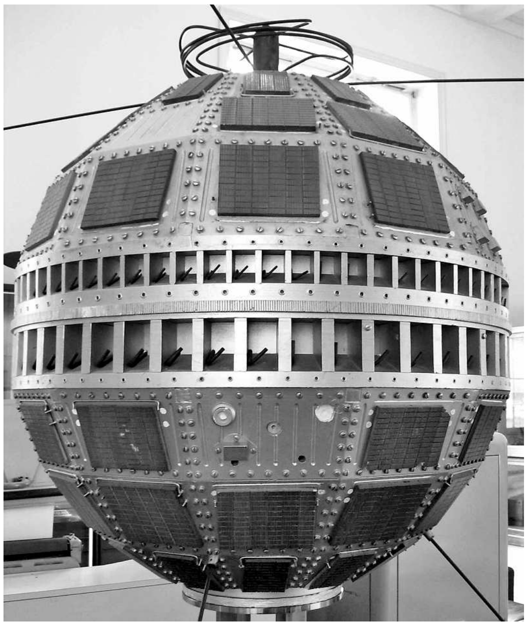
The Pleumeur-Bodou earth station's antenna, although not used anymore, is now a major exhibit at the museum. It is 54 m long and 30 m high. It is mainly made of steel, but its reflector and cornet (ear) are made of a light alloy of magnesium and aluminium, weighing only 340 tons. To protect the antenna from the wind, rain and bad weather it was put it in a huge white ball (radome), made of Dacron[1] filled with air, just like a balloon.

In the 1960s, making overseas telephone calls to and from Europe was still difficult and the transmission of images across the ocean was almost impossible. Therefore, something needed to be done because local and global communication needs were growing rapidly. The era of radio, television and computers was on its way.

In 1961 an agreement was signed between France, the UK and the USA, to develop an active communications satellite to relay television, telephone and fax traffic between Europe and the USA.

Two earth stations had to be built, designed to exchange signals with the earth station at Andover in Maine, USA. One was erected in Goonhilly in Cornwall, UK and the other in Pleumeur-Bodou, France. To complete the package, on 10th July 1962, Telstar, the first commercial telecommunications satellite, was launched from Cape Canaveral.

VK2IXV at the Pleumeur-Bodou museum with the earth station antenna's huge radome in the background.



Telstar 1.

This first Telstar satellite was a non-geostationary satellite[2] and, whilst turning around the earth, it provided a window of opportunity for 20 minutes per rotation. That meant the satellite could be seen at the same time from France and the USA only during 20 minutes of its 2 hour 37 minute orbit.

At Pleumeur-Bodou an automatic tracking antenna had to be built, with a precision of 1/100th of a degree, to track down the satellite in order to pick up the TV broadcasts.

Telstar 1 was able to receive television broadcast channels and telephone channels in the 6 GHz band, convert them to 4 GHz and then amplify the weak signals before retransmitting them back to earth.

Telstar 1 was exposed to the unknown effects of radiation and collision with cosmic particles; on 22nd February 1963, after 7 months of service, it stopped responding. However, by that time, other communication satellites were in operation to take its place.

Since that historic moment in July 1962, telecommunication techniques have drastically improved. Nowadays, a network of submarine cables and optical fibres covers the earth, whilst in space there are numerous geostationary telecommunications satellites transmitting pictures, sound and data all over the world for business, pleasure and general information.

Footnotes

1. Dacron is a polyester material with good durability and stretch.
2. Geo = Earth. A geostationary satellite is going around the earth at the same speed as the earth's rotation. To ground observers a satellite in a geostationary orbit appears to stand still and is always at the same point in the sky. This means that the satellite antenna of a ground station does not have to move, but can be pointed permanently at the fixed location in the sky.

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Book review:
The Tatura Secret Radio

Reviewed by **Peter Cosway VK3DU**
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When we think about secret radios in POW camps, we tend to think only of those secret radios built by members of the Allied forces in POW camps during WWII. This book, however, is an account of a secret radio built in an Allied internment camp in Australia. It details how a Norwegian seaman was detained in Australia during WWII and how he built and operated an illegal radio receiver to get news from Europe.

The author, Haakon Nilsen, was born in Norway in 1917. He informs us that, as a boy, he developed a fascination for radio when it was introduced to the rural area where he grew up. He describes firstly building a one valve receiver. As his enthusiasm and knowledge grew, more elaborate sets were built with wire aerials to receive signals from Oslo and Copenhagen. When he grew older he sought employment as a seaman. His radio hobby continued and he built radios in his spare time on board ship.

As an amateur radio enthusiast reading this book, I wondered whether he developed an interest in this aspect of radio but it seemed that his interest was only in receiving various national and commercial stations. Amateur radio is not mentioned. Later in the book he expressed a lack of interest in Morse Code. For someone experimenting with radio in that era, I would have expected that some knowledge and appreciation of Morse would have been mandatory for an involvement in amateur radio.

He stated that he had been a seaman for about five years when World War II commenced. His ship arrived in Newcastle, NSW in 1940 and for various reasons (explained in the book) he decided to travel down to Sydney to join a different ship. He recalls that, at this time, his English language abilities were limited to a few simple phrases.

Authorities detained him and he was subsequently moved to the Tatura No 1 Internment Camp in country Victoria. The Camp held about one thousand civilian males. They were detained because they were considered to be a security risk due to their nationality. The Camp held a lot of Germans but only a few Danes, Finns and Norwegians. All mail into and out of the camp was heavily censored.

The author was very keen to get news from Norway and devised plans to build a short-wave receiver. He informs readers that many of the German internees were also interested in news of the war. The earlier attempts by Germans, with what were essentially crystal sets, had received only the 3SR AM station in nearby Shepparton.

He states that the Australian authorities were always suspicious that this sort of illegal activity could be attempted and internees with any radio, or even electrical experience, were watched closely. He surmises that, since he was a Norwegian seaman, he did not attract particular attention. He planned his radio with help from German internees with relevant skills and knowledge.

The author developed expertise with both the German and English language during his internment. The Camp had film projection equipment and spare valves were obtained for the project. Internees went out of the Camp on supervised work groups on neighbouring farm land. A battery radio was found in a farm shed and the valves were smuggled back into the Camp. The book does not provide any relevant circuit details but does describe how critical components were made.

For example, fixed capacitors were fabricated from paraffin impregnated paper and silver foil from chocolates and cigarette packets. The variable capacitors were built by a coppersmith in the Camp. Batteries were built by German industrial chemists from an old car battery found by a Camp working party. A sheet of roofing iron was insulated with rubber grommets and was used as an antenna. The author devised an aerial trap to limit interference from the strong AM Shepparton station.

The book describes how the radio was concealed and how it was operated at night. The author reports reception of short-wave stations from Germany and Japan as well as the BBC from England. In addition to accounts of the radio operation, and the subsequent discovery by Australian authorities, there are many details of life in the Camp. The Internees had assistance from the Red Cross but the author notes that he had no assistance from any Norwegian consul.

The author wrote the book in 1997. He states that he visited the Camp site in 1951 and again in 1996. In 1991, though, he read an account of the operation of the illegal Camp radio in an edition of the *Tatura Guardian* newspaper published in 1947. He considered that many of the newspaper article details were inaccurate and he was keen to give his version of events.

The book acknowledges assistance from Australian sources and contains pictures provided by the Australian War Memorial in addition to photos provided by the author. In my opinion, the book provides an interesting account of life in the Camp. The description of the construction and operation of the subject radio, along with the author's version of events, makes for entertaining reading.

The Tatura and District Historical Society run The Tatura Irrigation and Wartime Camps Museum and Shop. They stock copies of this book plus a number of other books providing details about the seven Prisoner-of War and Internee Camps that existed in that area.

There is also a lot of information in a web site at <http://www.taturamuseum.org.au>

The author is: **Haakon Nilsen**
The publisher is: **Nilsen-Parker Pty Ltd, of Gwandalan NSW 2259.**
The ISBN is: **0 646 31761 x.**

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The early days of IFF

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Many old-timers will recall the war surplus BC-966 IFF sets, freely available from disposals stores after WWII. I recall buying one from Waltham's Trading Company in Elizabeth Street, Melbourne in the 1950s. Although the BC-966 was not readily converted to amateur use, it was a source of useful parts. This was a very long time ago and it was only recently, when preparing another article on IFF (Identification Friend or Foe) for *OTN*, that I remembered my old BC-966 unit.

My fading memories somewhat refreshed, I decided to see what I could discover about the BC-966 and the use of IFF during WWII. I quickly discovered that there is a plethora of material and information about this subject available on the internet, particularly if you are interested in the technical details. My challenge was to write an interesting article which would not bore the *OTN* reader with too much detailed technical information. If you want more technical information, there are many sites on the internet which will provide you with full details.

Why the need for IFF

Since time immemorial the need to discriminate between friendly or hostile parties has been of utmost importance to all military units, be they sea, land, or air forces. Before the widespread use of aircraft in battle, which caused a sudden and drastic change in the art of warfare, it was relatively easy to determine who was your enemy.

The earliest means of successful IFF (**I**dentification **F**riend or **F**oe) was visual recognition using flags, banners, insignia and uniforms which allowed adversaries to distinguish their friends from their enemies. In darkness, when those visual means of identification were impossible, the business of using passwords and countersigns achieved the same result. Also, the Naval method of identification by blinker (Aldis) light was used but, of course, in doing so at night, the sender disclosed his position to the challenged contact.

These systems worked for millennia as long as conflicts were more or less face to face and visual identification was possible. But, just over 70 years ago as World War II began, the widespread use of aircraft caused a dramatic and inexorable change. Now threats could approach with such swiftness that, by the time visual identification was possible, it was often too late to prevent destruction. All too often battle zones quickly became chaotic mixtures of friendly and hostile forces with many isolated units operating autonomously. In these circumstances visual identification was very prone to errors.

A WWII BC-966 receiver, part of the IFF Mark IIIG system.

The failure to recognize a piece of equipment or group of troops as being friendly has occurred throughout history. For instance, during WWI the Royal Flying Corps often complained that it was 'believed by none and fired on by all'.

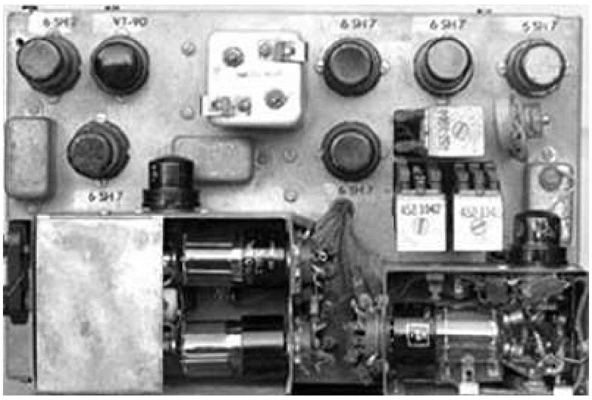
Modern examples include the destruction of large numbers of Luftwaffe aircraft by German anti-aircraft guns during their Operation Bodenplatte in 1945, the clash between British Special Forces units in the Falklands, and several incidents of 'friendly fire' during the first Gulf war where, I understand, some 20 per cent of US fatalities came from friendly fire. The culprit in almost all of these cases was visual misidentification, but the failure to recognise friendly equipment is not the preserve of surface forces alone. Air forces have been known to engage their own side by mistake on countless occasions.

Although radar was being developed before WWII and was extremely helpful in that it could detect incoming aeroplanes beyond the line of sight, it could not tell if they were hostile or friendly. It is a fact of history that the incoming attack on Pearl Harbour was noticed by the US radar station at Diamond Head but the Japanese planes were mistaken for an expected flight of American planes. The course of WWII in the Pacific may well have been changed if the incoming American planes and the radar station had been equipped with IFF.

Incidentally, please note that the term 'Identification Friend or Foe' is somewhat of a misnomer, as IFF can only positively identify friendly targets, not hostile ones. If an IFF interrogation receives no reply or an invalid reply, the object cannot be identified as friendly, but at the same time it cannot be positively identified as a foe. There are many reasons for friendly aircraft not to reply to IFF, such as battle damage or equipment failure, loss of encryption keys, and wrong encryption keys.

The first WWII IFF systems

The first example of an IFF system in WWII, albeit a crude system, can be attributed to the Germans. Early in the European conflict of WWII, British airmen were puzzled by the strange behavior of German fighter aircraft. Occasionally, and without apparent reason, the German planes would simultaneously roll over. The British eventually intercepted radio signals from the ground that always preceded this manoeuver. It was then realised that by rolling over at a predetermined signal the Germans were changing the polarisation of the radar reflections picked up by their own ground



Inside top view of a BC-966 transponder. The three 7193s, six metal 6HS7 and two metal 6H6 valves can be clearly seen.

radars. They created a distinctive blip on the radars that differed from others so German radar operators could identify their friendly forces.

The need to identify what was being detected by radar was considered at the same time as radar was being developed in various countries prior to WWII. In the first instance, in both the UK and the USA, IFF consisted of a simple dipole mounted on the friendly vehicle, resonant to the radar frequency and switched open or shorted so that it produced a fluctuating radar echo as an identifying characteristic.

The main beneficiary of electronic IFF was the air force but land and sea units were also fitted out. The first Allied trials were made with a British Handley Page Heyford bomber, a twin-engined biplane of wooden construction, which had a wire IFF antenna attached across its wings. This simple system suffered from lack of distance, unacceptable variability and could only respond to one frequency. Basically, it didn't work.

Pipsqueak

A later method of identification that was introduced was the use of HF/DF (**H**igh **F**requency **D**irection **F**inding) which was known to most as 'Pip-squeak' the code name given to the apparatus.

All British fighters were equipped with an HF (4.3 - 6.6 MHz) TR9D transmitter/receiver. This was the only (automatic) contact that a pilot had with ground control, although its main drawback was that it was limited to a range of only 40 - 45 miles (64 - 72 km) at about 15,000 feet (4,572 m) although under perfect weather conditions this range could be extended further.

The unit had two channels one of which was used for the purpose of voice communication with the Sector Control to which the aircraft was attached. Each squadron had its own frequency and always operated with this setting. The other channel was set on a common frequency to all squadrons and was unsuitable for voice communication. It was this channel that was known as Pip-squeak.

As soon as this channel was selected, the transmitter sounded a shrill fourteen second whistle at about 1,000 cycles (Hz), which was received by the Sector Controller.

Automatic periodic DF transmissions from aircraft were achieved by Pip-squeak which switched on the aircraft's HF transmitter for 14 seconds in every minute. A clock in the control room showed (from four coloured sections) which aircraft (in a section of four) should be transmitting (by a hand rotating once per minute).

Each aircraft had its position plotted once per minute. If the pilot forgot to select the automatic system, the controller would query, "Is your cockerel crowing?" (note the similarity to 'Parrot squawking' mentioned later).

The DF system and GCI (**G**round **C**ontrolled **I**nterception) radar were the keys to interception and meant that wasteful standing patrols were unnecessary. HF was often badly distorted and sometimes suffered both QRM and QRN. There was neither a volume control nor AGC on the TR9D's TRF receiver. VHF was badly needed but although the first sets were being produced by the time the Battle of Britain started, by September 1940 only sixteen day fighter squadrons were VHF equipped. TR9Ds were the mainstay during the Battle of Britain.

When Pip-squeak was transmitting it meant that the pilot could not use his transmitter or receiver during that 14 seconds or, if he was in the middle of transmission when Pipsqueak was transmitting, he would be cut off.

In practice, it is doubtful whether it fulfilled its intended purpose of identifying the location of friendly aircraft and it was probably a distracting nuisance for the pilots in that they had to watch that clock before transmitting a message.

IFF Mark I

By 1939, the IFF Mark I had been developed and, in late September and early October, Spitfires started being fitted with this equipment. It was an improvement on the passive dipole and Pip-squeak systems, consisting of a receiver/transmitter carried in the plane that was to be identified. The IFF set was normally in the receiving mode but, when energised by a radar signal, it broke into oscillation and became a transmitter.

The return signal mixed with the radar return to provide a distorted and identifiable echo. The tuning of the IFF set was mechanically swept across the band of frequencies covered by the radar sets in use so that each radar would receive a response when the receiver matched the radar's frequency. At this time the predominant UK Chain Home radars operated at frequencies between 20-30 MHz. The IFF receiver and transmitter antenna wires emerged from small insulators just in front of, and slightly above, the red centre spot of the fuselage roundels on both sides and were anchored to the tips of the tailplane.

A British Handley Page Heyford twin-engine biplane bomber of the 1930s.

The wire IFF antenna and VHF radio antenna can be clearly seen on this Spitfire Mark Vb. The insulator for the IFF wire to the tailplane can be seen on the centre part of the fuselage roundel.

IFF Mark II

IFF Mark II was developed to cope with the additional frequency bands of the newer radar sets and covered these in three swept ranges, including the original IFF Mark I band. However, radars were advancing at such a rate that quite quickly IFF Mark II was unable to cover all the radar frequencies in use. Variations were produced for these other radar bands, such as the IFF Mark IIG and Mark IIN which were British sets for UK radars, and the USA SCR-535 and SCR-535A which worked with the early US Army radars

The IFF Mark II was designed to allow switching between any one of six different coded responses, usually specified for various types of mission. But in practice it proved difficult to distinguish one echo from another so generally only position 1 (or A) was used, whilst the longest, widest response position was used universally as a distress signal.

In order to respond to the growing number of radars in service, an aircraft or ship often had to carry multiple IFF units. The services soon recognised that, with the proliferation of radar and other equipment, there was a need for a distinct frequency band for IFF with a common equipment specification.

Also, the development of centimetric radars by the Allies meant that aircraft needed improved IFF units, since the older British IFF Mark II could not be modified to cover the shorter wavelengths.

IFF Mark III

The British then developed and manufactured the IFF Mark III, a system that was compatible with any radar since it didn't pay any attention to radars to begin with. Although its predecessors responded to radar signals at specific wavelength ranges, this earlier approach was inflexible and also too easy for the Germans to work out.

This new IFF was a standardised system used by the Allies where the IFF Mark III designation referred to the complete system including the transmitter, receiver, control boxes, and coding units, etc. The components of the IFF MK III included the 'interrogator' (a radio transmitter located close to the ground radar set and interfaced with it to transmit between radar pulses) and the 'responder' (a receiver also attached to the radar set, usually in the same box as the interrogator, that received the return identifying signal and processed it for display on the radar screen - the receiver was automatically switched so that it was not overloaded by the radar pulses).

The receiver tuning of the IFF Mark III transponder was swept across a limited band of frequencies allocated for the purpose, whilst the interrogators were set on spot frequencies within the range of 1.9 to 1.6 metres (158 to 188 MHz). This overcame to a large extent the problems of mutual interference and multiple responses to numbers of radars in any one area.

In addition, the interrogator only needed to be pulsed when needed, to get a response from an unknown radar blip. This was better than having the transponder being activated all the time by the primary radar, which would have meant that there were continuous replies from the transponders which would have been of great interest to the enemy! (Transponders are also known as secondary radars, as distinct from 'direct' or primary radar where the return is a reflection of the primary signal rather than a response triggered by the transponder.)

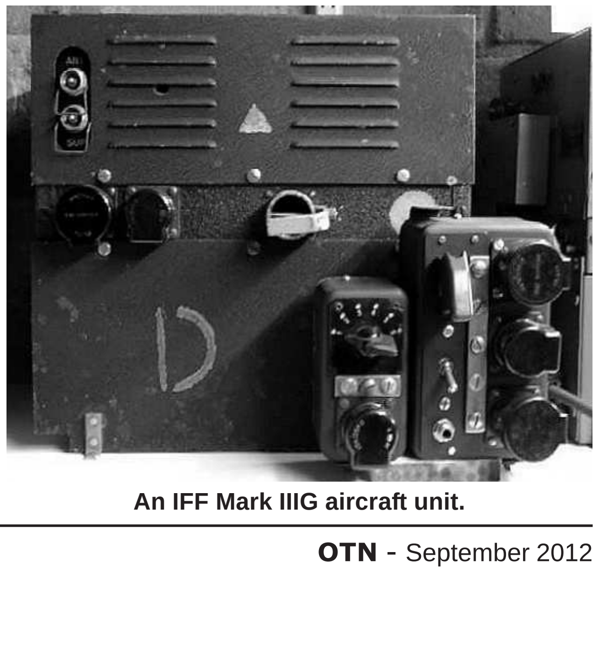
The IFF Mark III also eliminated the troublesome adjustments required by its predecessors. It was built in great quantity and in early 1943 the new IFF Mark III began to be fitted to all front-line fighters. On the Spitfire the fuselage to tail plane antenna wires were replaced by a single rod antenna mounted under the starboard wing.

However, the Americans weren't entirely happy with IFF Mark III and pushed for their own IFF design. The British defended the technology and had the upper hand in the bargaining because they were already putting the IFF Mark III into production. Since IFF had to be standardised to be effective, the Americans had no choice but to grudgingly go along, holding their own technology, which became known as IFF Mark IV (operating around 470-500 MHz), in reserve.

The NRL (US National Radio Laboratories) also developed by the end of the war the IFF Mark V which worked in the 950-1150 MHz band. The best known version of this system was the APX-6 transponder which lent itself to conversion to the amateur 1296 MHz band when it appeared on the post war surplus market.

Notwithstanding the above, for the sake of standardisation over the vast numbers of British and Allied equipment being used in Europe, a decision was finally made that the IFF Mark III would be the IFF standard for the aircraft and ships of the Western Allies by the spring of 1943.

The IFF Mark III proved successful, although not entirely so. One problem was that trying to interrogate a single aircraft in a large formation led to a large



An IFF Mark IIIG aircraft unit.

number of IFF responses. Such 'IFF clutter' made it hard to determine if an unknown aircraft in a night bomber formation was a member of the formation, or a 'wolf in the fold'.

Another problem was due to the fact that the interrogator and IFF unit used the same wavelengths, which caused confusion when an IFF unit triggered the IFF unit of another aircraft. Also, when used on ships, IFF Mark III's behaviour on the surface of the ocean was different than in the sky, resulting in a number of 'friendly fire' incidents.

Then there were the simple difficulties of making sure people used the IFF system properly. Figuring out if an IFF unit was working was trickier than checking, say, a radio and so malfunctions were easily overlooked. Aircrews were trained to turn off the IFF when over hostile territory so the enemy couldn't use it against them, but sometimes they would forget to turn it back on when they came home and received a very nasty reception.

I understand that some WWII aircrew nicknamed the IFF 'Reply or Die'. There were so many incidents due to bungled use of IFF that a 40-minute training film was developed in 1944 to pound it into people's heads how to do it right and to emphasise what unpleasant things could happen to them if they didn't.

As stated earlier, the WWII IFF system did not provide an absolute means of recognising radar contacts. Therefore, to help insure that the responses were authentic, it was important to deny the enemy use of any transponders that he may capture. As a means to this end, all transponders were provided with small explosive charges which could be detonated either by an impact switch operated by the deceleration of a crash landing, or by a switch to be operated manually by the pilot whenever there was a possibility of the plane falling in enemy territory.

The case of the transponder was designed to withstand the force of the explosion without rupture so that there was little danger to operating personnel from the explosion. The small charge used was intended primarily to make the set entirely useless but not to conceal all details of the operation.

Incidentally, the BC-966 I purchased as war surplus nearly 60 years ago was the transponder unit, operating over a frequency range of 158-188 MHz, and was part of a further development of the IFF Mark III designated the IFF Mark IIIG. I am told that some of these sets actually were accidentally released with the charge still fitted!

German IFF

It is interesting to note that the Germans also developed an electronic IFF, called the FuG-25a 'Erstling', in 1940. It received the radar frequencies on 125 MHz (the German Freya radar) and also on 550-580 MHz (the Würzburg radar).

To start the identification procedure, the ground operator switched the pulse frequency of his radar from 3,750 Hz to 5,000 Hz. The airborne receiver decoded that and started to transmit its code. Before departure, two mechanical keys of 10 bits each were inserted into the reader. The IFF transmitter worked on 168 MHz with a power of 400 watts PEP.

Unfortunately for the Germans, however, the British were able to build their own IFF transmitter, called 'Perfectos' which, when mounted into a RAF Mosquito, could trigger the FuG-25a and therefore betray the position of the German night fighters. To minimise that happening, the German pilots had to switch off the FuG-25a for much of the time they were in the air.

The US Army Air Forces in Europe used two types of IFF Mark III. The first was the Radio Set SCR-595 which was actually a Navy set, designated the ABK. It was the US version of the British IFF Mark III transponder, the R3090, and was mechanically and electrically interchangeable with it. This transponder was fitted to bombers and transports but not to fighters which generally came under GCI control.

The other was the Radio Set SCR-695 which was an American built set used by the US Army Air Forces and the US Navy, as well as the RAF, and was similar to the British IFF Mark IIIG transponder, the R3121. This set could be installed in any aircraft because it had the additional fixed frequency response for GCI action.

Away from the European theatre of war, the US built quite a number of different models of interrogator/responder sets to cover the different operating spot frequencies associated with each new type of radar.

After WWII

After WWII, with rapid technical developments creating new high performance aircraft, the need for efficient and reliable IFF systems led to a long series of further refinements that eventually evolved into the modern IFF systems in use today. But that is a subject for another day!

During WWII, IFF was code-named 'Parrot'. Aircrews were instructed to use their IFF set via the term 'Squawk' and to this day the terminology still exists.

These days IFF is called a transponder and has 4096 possible codes, so an ATC controller will instruct a pilot to 'Squawk Code XXXX', together with a specific mode, possibly one that refers to an altitude reporting capability which early IFF systems did not have. Various modes exist from Mode 1 to 5 for military use, and Modes A, B, C, D and S for civilian use. The military Mode 3 equates to civilian Mode A.

The radar 'paint' from early IFF gear was quite broad and, if several IFF equipped aircraft were operating in close proximity, the individual returns from each aircraft were blurred together. The radar operator would therefore ask each aircraft to "Strangle your Parrot" so that the returns could be separated more clearly. Today's controllers use the expression "Squawk Standby". Not surprisingly, very few of today's pilots would know where the 'Squawk' terminology originated.

Today's **T**raffic **C**ollision and **A**lerting **S**ystems (TCAS), which warn pilots of impending or potential collisions and which can issue verbal instructions on collision avoidance manoeuvres, are a further development of IFF. Most airliners are so equipped but it is still too expensive for private flyers though simpler systems based on GPS positioning are becoming accepted.

Basically, TCAS equipped aircraft transmit a signal which, if intercepted by another aircraft, calculates the collision risk by comparing tracks and altitudes. The presence of a nearby aircraft causes an 'advisory' to be generated but if an actual collision risk exists then an escape path is calculated and aural warnings and verbal commands such as "Pull-up, turn right" are issued. TCAS does not use GPS but gets its data from the aircraft's air data computers.

Sources

- A multitude of sites on the internet, far too numerous to list.
- Former post-WWII RAF fighter pilot and Qantas pilot, Clive Wallis VK6CSW.

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A modern variation of the Selsted-Smith AM detector

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I have an ongoing interest in the rapidly becoming old fashioned method of modulation called AM. Over the years, using crystal sets and diode detectors as my basis, I've come up with some pretty good low distortion AM detectors that make AM sound great (see <http://sound.westhost.com/articles/am-radio.htm>).

Many of these detectors are diode based but, when aiming for high quality results, diode detectors can be painful.

They like a fair bit of input signal and, just as important, the output loading (AC/DC ratio) needs to be optimal. These issues can be overcome with good design. There are also other simple circuit approaches to AM (amplitude modulation) detection which can work well such as the 'infinite impedance' detector originally designed around triode valves.

These translate well to modern circuit equivalents such as the field effect transistor (FET). However, although less problematical and fussy than diode based detectors, they still have audio distortion issues under conditions of high percentage and boosted asymmetrical modulation techniques commonly used by AM and FM broadcast stations today.

I might have found a solution courtesy of another old valve based AM technique of the past, the so-called 'Selsted-Smith' AM detector. This detector remains contentious in some quarters; however, I have found its translation to modern circuit techniques works extremely well, giving very clean AM detection under adverse test conditions.

The original Selsted-Smith detector consisted of a valve diode directly coupled into a triode valve cathode follower with RF filtering on the output of the cathode follower stage (see the sidebar). In my version, I used a BAT46 silicon Schottky diode feeding directly into the gate of my 'active load' FET source follower, with a second FET configured as a 'constant current source' for reduced distortion and overall linearity in the source follower FET stage which, incidentally, works fine as an infinite impedance detector in its own right.

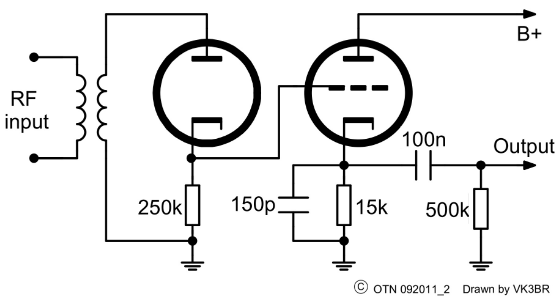
However, the addition of the diode cleans up the audio quality very nicely and the output level is actually slightly higher as well! I don't know if the circuit, Fig 1, is completely optimised, but it certainly works well and produces great sounding audio from AM broadcasting stations!

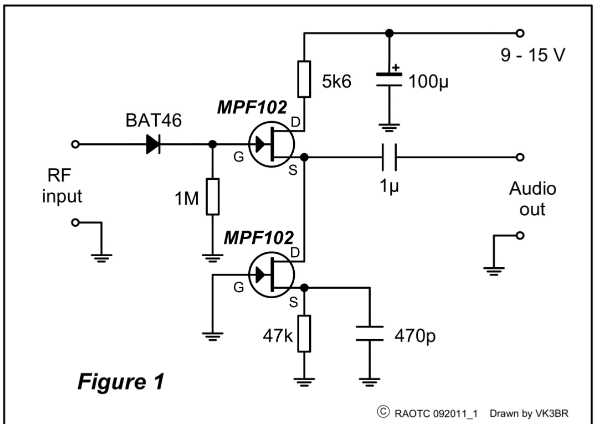
This modern 'solid state' variation of the old Selsted-Smith' AM detector works extremely well!

Low distortion AM detector

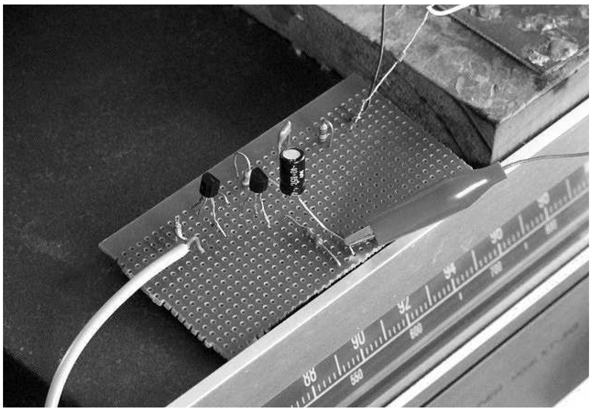
A low-distortion AM detector was developed by W T Selsted and W H Smith many years ago. This consisted of a conventional diode rectifier direct-coupled to a cathode follower which is in turn connected to an RF filter to reduce the carrier signal output (see circuit below). The excellent performance of this circuit is due to two facts:

1. That the load on the diode for normal AM carrier frequencies is essentially resistive, and the normal effects of excessive shunting capacitance are eliminated; and
2. That, since the coupling to the cathode follower is direct, there is no effect of biasing currents which are normally developed in a diode loading circuit using coupling capacitors. The distortion for 100% modulation is claimed to be 0.3% at a modulating frequency of 420 Hz and 0.8% at 4000 Hz. The carrier input voltage and frequency are not stated.





Circuit diagram of the modern variation of the Selsted-Smith AM detector.



The author's modern solid state version of the Selsted-Smith AM detector.

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The Phonopore

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This is a story about an early telephone which operated across a telegraph line. It was around 1943 when I first went north of Alice Springs and called in at several watering stops between 'The Alice' and Tennant Creek. It was at either Aileron or Ti Tree (I can't remember which) that I first saw this wall mounted telephone with a horn projecting from its front. It was quite different to any telephone I had seen before. I was to learn that this was a Phonopore, a relic of the original early telegraph which had operated all the way to Darwin.

The old telegraph circuit, some 3,000 km long from Adelaide to Darwin, operated over a single galvanised iron wire and earth return. Sections of the line were connected by eleven repeater stations roughly 250 km apart. Each station was manned by telegraph operators who transferred the telegraph data from one section to the next.

The Phonopore was a telephone which allowed speech to be sent and received over the same circuit as used for the telegraph. Before the balanced lines and the three channel carrier system replaced the early telegraph system, Phonopores were used between various locations on the route between Maree and Pine Creek. I imagine that, when I saw the Phonopore in operation, it was probably connected between the centre of the newer balanced line and earth. In the field of telecommunications, this is referred to as a Cailho circuit.

The Phonopore contained elementary filter circuits which reduced the low frequency telegraph impulses from interfering too much with the telephone receiver. It also cut off the low frequency components of transmitted speech so that they did not interfere with the telegraph circuit. With the low frequencies reduced, the speech did sound a bit 'thin', but still allowed communication.

The other difference between the Phonopore and the common manual magneto telephone was the calling system. The magneto telephone used a generator rotated by a handle to produce about 80 to 90 volts AC signal at a frequency around 20 hertz. This signal operated a bell on any other telephone connected across the line or a drop indicator on the remote manual telephone exchange. However this could not be used across the telegraph line as it would interfere with the telegraph signals. Instead, the Phonopore generated a high pitched call signal across the line from a mechanical vibrator or buzzer operated by a push button. The sawtooth waveform generated was around 135 Hertz and was probably rich in higher order harmonics. This would have accounted for the rather harsh high pitched sound.

Figure 1- The Collier-Marr magnetic receiver and horn.

For an incoming call, the signal actuated a very efficient electromagnetic receiver invented by A T Collier of Sydney in the 1880s. Coupled to the horn, this produced a loud audio note to attract the operator to the phone.

The electromagnetic receiver was manufactured by the Collier-Marr Company in Manchester, England. It owed its high output to the double diaphragm and massive coil assembly. An external horseshoe magnet was used to polarise the iron core of the coil. A diaphragm was set at each end of the iron core, between the core and the magnet's pole pieces. The Phonopore used a metal trumpet or horn to further amplify the sound. The Collier-Marr calling receiver is shown in Figure 1. It is also shown fitted near the top of the early Phonopore of Figure 3 on the next page.

Phonopore in the railways

At this point, I will diverge a little. My father spent a large part of his working life as a Signalman in the South Australian Railways Signal Cabin at Murray Bridge. As a boy, I was always fascinated by this cabin with its long row of massive levers which mechanically coupled to remote railway line switch points and remote signals. The back wall of the cabin was also covered with various electro-magnetic devices and numerous telephones from which he communicated with other operational places in the railway system. At least one of these telephones had an unusual horn.

After my return from the Northern Territory, I visited my father in his cabin and I then realised that part of the cabin operational communication system included a Phonopore. I guess I didn't attempt to find out what sort of line circuit supported the Phonopore. However, it probably was another Cailho circuit derived from one of the balanced telephone lines feeding other telephones in the cabin. Within our South Australian region of the PMG's Department I asked a lot of questions about the Phonopore but generally drew a blank. I guess it was never a common item in the Department in SA. However, it is clear from my own observations that it was certainly used by the South Australian Railways.

Early History

It is around 68 years since I first encountered the Phonopore in the Northern Territory and learned a little about how it operated. The fact that its existence seemed to be forgotten history encouraged me to look further. Some 68 years later, with the help of the references listed at the end of this article, I have been able to document more about its operation and early history.

The principles used in the Phonopore were devised by Francois Van Rysselberghe who was a Professor of Physics at the Industrial School of the Ostend School of Navigation. He patented his system in 1882 and provided details of a number of circuits to handle

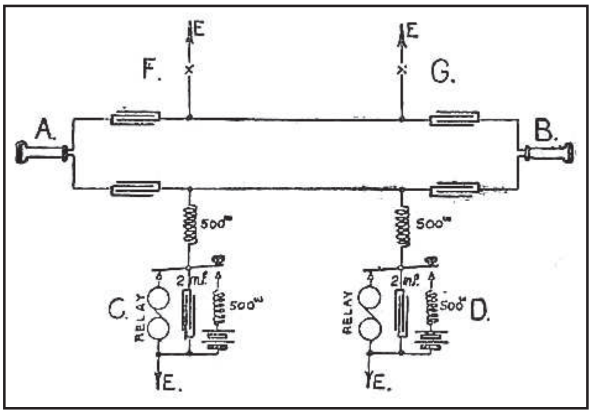

Figure 2 - The Van Rysselberghe Circuit (Note: The C and D circuit is duplicated at F and G).

different configurations of lines, both single-wire and full metallic (two wire).

The circuit of the Van Rysselberghe system, as taken from *The Practical Telephone Handbook*, 1912 by J Poole, is shown in Figure 2 above.

Early Phonopore of the 1980s

A description of operation, concerning the diagram in Figure 2, has been reassembled from the original text in the Poole handbook. The name 'Phonopore' as a special type of telephone is not mentioned in the handbook and it simply refers to the telephony instrument as the 'telephone'. For the purposes of describing just the Van Rysselberghe circuit, my version of the text which follows will also use 'telephone'.

Two telegraph terminals are shown on the diagram in an abbreviated form at C and D. Symbols at A and B represent the two complete telephone terminals.

Inclusion of high inductance coils in series with the battery and the telegraph line provided sufficient reactance to impede components within the voice frequency range and reduce their presence in the telephone circuit. The level of the voice frequency components generated by the telephone were also insufficient to affect the operation of the telegraph instruments as telegraph circuits work at quite high voltage. Whilst not mentioned in Poole, I assume that the capacitance shown in series with the telephone circuits was also limited in value so that the low frequency telegraph components into those circuits were attenuated. With this arrangement, simultaneous operation of both the telegraphy and telephony was achieved.

By making the telephone circuits return through a second telegraph line fitted in a similar manner, a balanced telephone circuit was achieved. The second telegraph circuit is shown at the top of Figure 2 with telegraph terminals F and G, which are identical to C and D but for simplicity are not fully redrawn. In its balanced form, the telephone-derived line operated free of induction from the two telegraph lines.

Poole reports that the Van Rysselberghe system has been extensively used on the State telegraph lines in Belgium and on a number of railway lines in other countries. It has also been used for trunk line call-wire circuits by the British Post Office.

With each telephone (or Phonopore) connected between the two telegraph lines, one could describe the arrangement of Figure 2 as a form of phantom circuit (a telephone balanced circuit derived by connecting between two Cailho circuits is often referred to in telecommunications as a phantom circuit). The Van Rysselberghe balanced circuit is a bit different to that used on the early Adelaide-Darwin telegraph as, in the latter, there was only one telegraph wire operating against a ground return. Hence, the Phonopores on the early Adelaide-Darwin line also had to operate unbalanced against ground.

The Phonopore found application in different forms throughout the world in the late 1880s and the early 1900s. They were used by many railways to provide voice communication over their telegraph circuits without the need for additional telephone lines.

One interesting feature of many instruments, such as the one shown in Figure 3 below, was the inclusion of two telephone earpiece receivers. It has been explained that this reduced interference from the telegraph signal. This puzzled me a bit but I figured that this interference was possibly residual acoustic noise coming via the horn. Perhaps one reduced this interference by clamping an earpiece on each ear to attenuate the external interference. However, this operation might have been difficult if one of the two hands holding the earpieces was needed to write down a message.

Inside the Phonopore

Figure 4 on the next page is a photo of a typical Phonopore with the front cover removed. The push button which operates the buzzer for calling is shown at the centre of the photograph and the call generating buzzer is at the upper right.

The transformer (or induction coil) and the typical solid back carbon granule transmitter are clearly shown. However, the Collier-Marr magnetic receiver with horn is unfortunately cut off by the top of the photograph. The transformer is a requirement of all telephones using a carbon granule transmitter to match the transmitter circuit low impedance (around 60 ohms) to the nominal line impedance at voice frequencies of 600 ohms. The transformer also isolates the low resistance transmitter circuit from the higher resistance magnetic earpiece receiver and the line resistance.

Figure 3 - An early Phonophore of the 1890s.

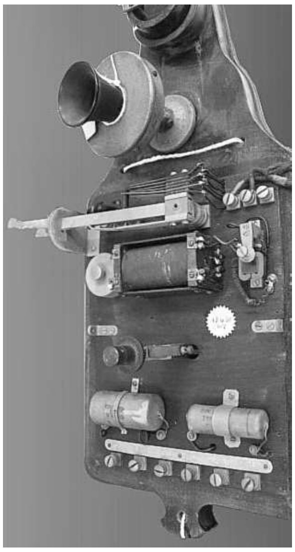

Figure 4 - Phonopore with front cover removed.

As with similar carbon granule transmitters on Magneto type telephones, the transmitter circuit would have been supplied with 3 volts from two 1.5 volt cells in series. Two of the terminals at the bottom of the photograph provide for battery connection. The other terminals are assumed to be there for line and earth.

Both capacitance and inductance are normally needed to form effective passive band separation filters. Whilst there are capacitors shown in the photograph, I am not clear on how the inductance was derived to separate the telephone and telegraph circuits for this particular Phonopore sample. Perhaps this was somehow provided by inductance within the transformer assembly.

Phonopore manufacturers and the BI&H Pantophone

During the late 1800s and the early 1900s there were a number of companies which manufactured a model of the Phonopore. An early maker of the Phonopore was Mr C Langdon-Davies who distributed his units through his British company the Phonopore Construction Co Ltd. There were other company names such as Ericssons, Medhurst and Siemens, and also the Australian Post Office.

British Insulated & Helsby Ltd (BI&H) made various telephone units including a type of Phonopore that they called the Pantophone (shown in Figure 5). At least one reference called this the Phantophone. I wondered whether this was an original name based on the idea that the telephone system was a phantom circuit superimposed on the telegraph line.

Figure 5 - The British Insulated & Helsby Ltd Pantophone.

From the Pantophone photograph, it is clear that the Collier-Marr type of calling signal receiver has been replaced by a different unit of some kind. Also the earlier, solid back transmitter has been replaced with an Ericsson insert transmitter following a trend in later telephones. The removable inset module in the Ericsson transmitter allowed easy repair in the event of the transmitter becoming noisy or inoperative.

The two hand held earpiece receivers followed the arrangement used in other Phonopore units to reduce telegraph interference. It is strange that, in this unit, two different models of earpiece were fitted.

The Australian Tele 41 Phonopore

Prior to 1914 the Australian Post Office produced their own model of the Phonopore (the Tele 41) in the Post Office Workshops, Melbourne. A photograph of the Tele 41 is shown as Figure 6.

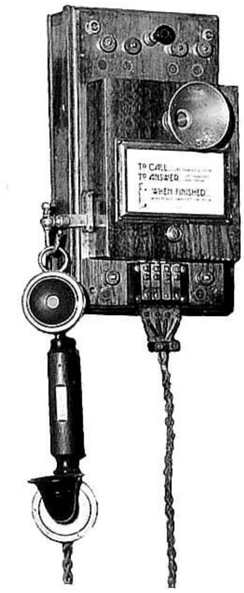

Figure 6 - The Australian Post Office Tele 41 Phonopore.

In this model they replaced the Collier-Marr receiver with an Ericsson type of electromagnetic receiver for reception of the calling signal. Also, a send and receive handset replaced the fixed, solid back, carbon granule transmitter and the floating earpiece type receiver. It is interesting that they apparently no longer needed two earpiece receivers to reduce interference from the telegraph signals.

One reference indicates that the Post Office stopped manufacture of the Tele 41 around 1920. Telegraphs were in common use by many of the railways in Australia.

At one stage, the Australian Post Office leased space on Railway Telegraph Lines to run Phonopore circuits to local Post Offices. These were eventually replaced by more convenient telephone networks.

Phonopores of various types were in use in many of the Railways. In New South Wales the Phonopores were largely replaced by telephones in the 1930s but the last two were only taken out of service in 1962.

I now wonder whether the Phonopore I saw in the Northern Territory around 1943 was an Australian made model or otherwise. The same question arises concerning the Phonopore in my father's railway signal cabin.

The early Phonopore is indeed now a rare collector's item.

Incidentally, there is reference on the Internet to one being held by the Powerhouse Museum in Sydney. I wonder where other remaining relics might be found.

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