Some milestones in electronics

An interview with Professor Bernard Tellegen

by Arthur Garratt

Professor Bernard Tellegen, now aged 79, at the Natuurkundig Laboratorium in Eindhoven, Netherlands

In this article Professor Bernard Tellegen, inventor of the pentode, discoverer of the Luxembourg Effect, pioneer of the gyrator and great figure in the history of radio talks to Arthur Garratt, a British scientific and industrial consultant now living in France.

BEFORE the invention of the transistor, the three most significant inventions in radio were the diode (Ambrose Fleming, 1904), the triode (Lee de Forest, 1906) and the pentode by Bernard Tellegen in 1926.

The pentode originated in the Philips Research Laboratories, the *Natuurkundig Laboratorium* or *Nat Lab* as it is generally called, at Eindhoven in the Netherlands.

The Nat Lab was set up in January 1914 under the directorship of Dr Gilles Holst, who had previously worked in Leyden with Kamerlingh Onnes – one of the great figures in low temperature research. Holst soon had an assistant, Dr Ekko Oosterhuis, who became Holst's second-in-command. (Oosterhuis, incidentally, was the grandfather of the British golfer, Peter Oosterhuis.) After the first world war the Nat Lab grew apace and among other well-known members of its staff were Balthasar van der Pol who published some two hundred papers on theoretical aspects of radio, with particular emphasis on relaxation oscillations, and Klaas Posthumus who, as we shall see, was a co-discoverer of negative feedback and also carried out pioneer work on split-anode magnetrons. Apart from Bernard Tellegen, a prolific generator of ideas who still comes to the Nat Lab regularly to "work on things which interest him" and Klaas Posthumus, the other men we have mentioned are now dead.

Arthur Garratt visited the Nat Lab at Eindhoven and recorded an interview with Bernard Tellegen who explained how the pentode and gyrator came into being and also traced the history of wave interaction in the ionosphere, the so-called Luxembourg Effect.

Bernardus Dominicus Hubertus Tellegen, to give him his full name, was born in 1900 and trained as an electrical engineer at Delft Technical University, graduating in 1923. After completing his military service he joined the Nat Lab in May 1924 and spent his entire working career with Philips. Arthur Garratt asked him if he immediately joined Van der Pol's radio group:

TELLEGEN Not immediately, this happened a few years later. When I first joined Philips I worked with Oosterhuis. One of my first assignments was a tungsten arc lamp which had recently been developed in the Nat Lab. This operated well on d.c. and we tried to make it work on a.c. by using some kind of transformer – unfortunately this was not successful. After that I worked on the development of a battery eliminator; this was taken over by someone else who carried it through to production.

It was after this that I joined Van der Pol. From the beginning I was more theoretically than practically minded and this naturally caused me to gravitate towards Van der Pol, and I started in the field of radio about which I didn't know a great deal at that time. However, I studied a paper of Van der Pol's – a general paper on electron paths; this was my introduction to radio. I then began to study amplification. W. Schottky had written some papers on screen grid tubes (tetrodes) and these interested me very much. I also read papers on the use of triodes as output tubes and I observed that the triode should have a low internal resistance in order to get the maximum output. Then I put the two tubes together in my mind – I realised that with the tetrode you move the anode-current/grid voltage characteristics over to the left and this was clearly a desirable thing to do. I did some calculations – nothing about secondary emission at this stage – and I came to the conclusion that a screen grid tube, notwithstanding its high internal resistance, was very well fitted to the role of an output tube. You must remember that these were the days when the anode supply was from dry batteries and we wanted the maximum output from a given battery voltage. From this starting point I saw that one should not only get a higher output but also greater stage gain and less frequency distortion because the current in the loudspeaker should then be proportional to the control grid voltage. Putting all these things together led me to the conclusion that a tetrode should make an excellent output tube.

Of course, when you try this out you immediately come up against the problem of secondary emission. Secondary electrons are always emitted when primary electrons strike an electrode with an energy above about 10eV. In a triode they have no effect because they are drawn back to the electrode from which they are emitted, but in a screen grid tube secondary electrons emitted from the anode are attracted to the screen grid when the anode potential falls below that of the screen. This produces impossible distortion if the tube is driven hard – as an output tube must be. So I introduced a suppressor grid between the screen grid and the anode – this prevented the exchange of secondary electrons between the anode and the screen grid.

I talked with Holst about other means of suppressing secondary emission and he proposed some methods which were put into the patent – this was the reason that the patent itself is under the names of both Holst and me. In fact Holst's suggestions were never put into practice, the suppressor grid was successful and that was that.

GARRATT When you first constructed a tube with a suppressor grid, did it work right away or did you have to do more experiments?

TELLEGEN We had to do some experiments to measure anode current as a function of anode voltage at various values of suppressor voltage. You can find these in the original paper together with some of the results. The optimum dimensions for the suppressor grid were later studied by Jonker in the Nat Lab, but at the beginning we did not have much difficulty in finding a reasonable construction for the suppressor grid.