

Klystron Tubes

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The principle of velocity-variation, first used in Heil oscillators, was also used in other microwave amplifying and oscillating tubes. The application for klystron with integral cavities is usually credited in the early 1939 to Hahn and Metcalf and to Russell and Sigurd Varian, two brothers that worked for a while at the Stanford Physics Department with Professor Bill Hansen. Hansen had developed the theory of resonant cavities, named ‘rumbatron’, essential for the klystron operation. Sperry Gyroscope Company, interested in a blind-landing system, financed its initial development.

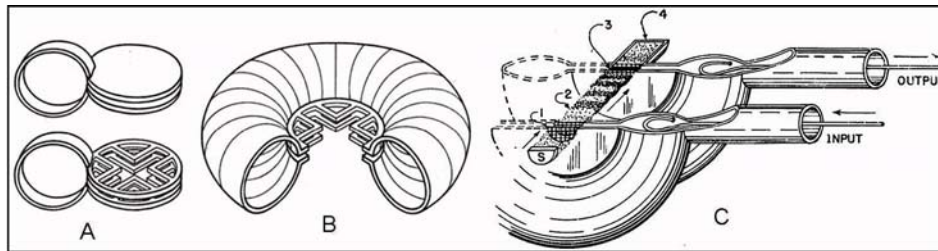


Fig. 1.1 – A and B show how the single turn LC resonator evolved in the ‘rumbatron’. The cavity may be considered as the result of many elementary sections, each being similar to A, all parallel connected. This connection results in very low inductance value. The shape of the capacitor in the middle of the cavity easily interacts with an electron beam. Q of this kind of resonator is very high. The early form of klystron amplifier is represented in C. Here the stream of electrons coming out from the source S crosses the short gap (1) of the first resonator. When passing through the gap, also referred to as buncher, electrons are subjected to acceleration depending upon the instantaneous value of the electric field between the capacitive rings. As result of the impressed acceleration, some electrons speed-up while other slow-down, to form bunches of electrons in the drift space (2) where no external field is impressed. The electron beam, whose density is now modulated by the input signal, crosses the second gap (3), also known as catcher, delivering energy to the cavity and to output. Electrons are then captured by the collector (4).

The linear beam klystron

Two forms of such a device, also called ‘linear beam klystron’, are given in the following figure.

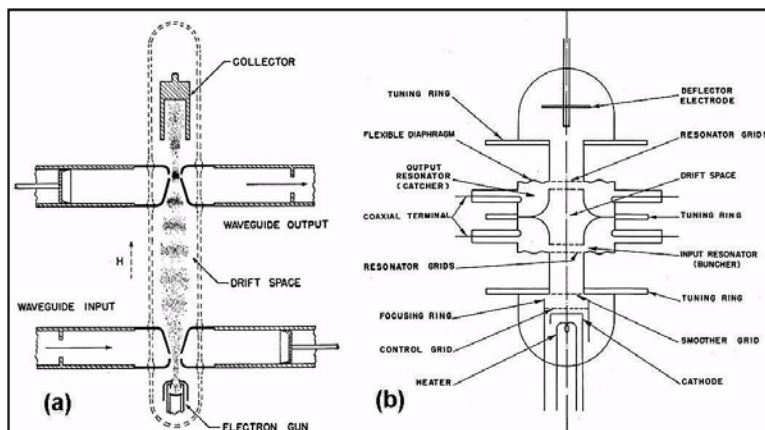


Fig. 1.2 – Left, draft of a linear beam klystron with external resonating cavities, in this case part of input and output waveguides. Right, in this early Sperry design the resonating cavities are embedded in the tube itself and flexible diaphragms allow some tuning. The collection includes a sample of this very early structure.

In fig. 1.2(a) the tube has four copper rings, the solid black sections, which form the capacitive gaps inside the glass body and connect to the waveguide resonating chambers outside. In the second



Fig. 1.4 – Linear beam klystron tubes developed by Bell Laboratories. 4(a), 4(b) and 4(c) are very early prototypes developed prior to WWII. 4(b), 4(f) and 4(g) are cascade types.

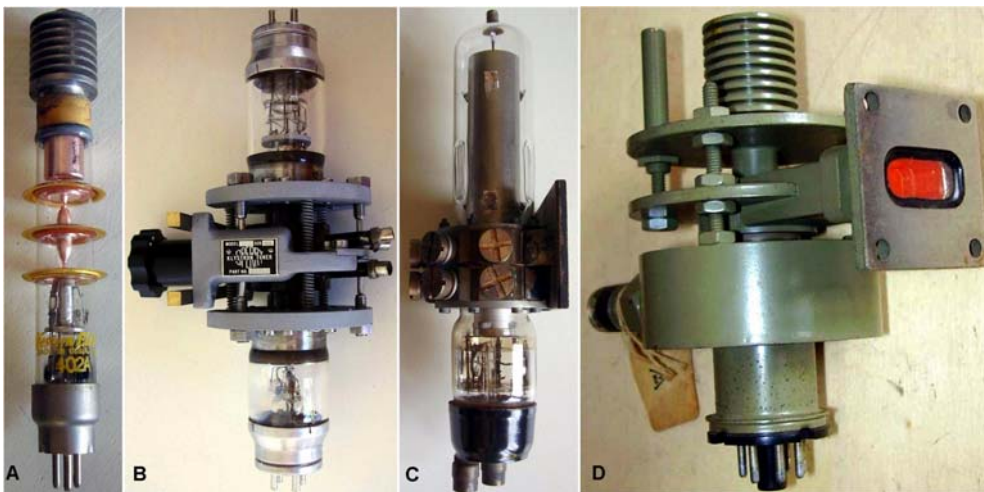


Fig. 1.5 - Linear beam klystron: A) [WE 402A](#) linear beam similar to the one identified as L.4(d) in fig. 1.4. Small production run by Western Electric. B) A sample of [Sperry early type](#) with its 11-C tuner. Likely this was the first industrialized type derived from the experiments of the Varian brothers at Stanford. Its internal schematic arrangement is given in fig. 1.2(b). C) [CV150](#) was intended as pulse transmitter at 3 GHz. It delivered 30 kW pulses with an efficiency of about 50%. D) The Varian [V-45](#) is a linear-beam frequency multiplier with coaxial input on the lower large resonating cavity and waveguide output. Click to enlarge.

Linear beam klystron tubes are too noisy for amplification of low level signals but have found relevant applications in high-power CW amplifiers, as television repeaters or CW radar equipment and even in microwave frequency multipliers. Below a high-power linear klystron, the [F-2004](#).



Reflex klystrons

Any linear beam klystron may operate as oscillator adding a feedback loop between output and input cavities. Anyway when a klystron must just be operated as oscillator its structure can be simplified, leaving only one gap and negatively biasing the electrode that before was the collector. In this type of tube, referred to as reflex klystron, the negative electrode is called repeller. Electrons that have already crossed the gap, being consequently bunched, are forced by repeller to cross back the same gap that now performs the function of catcher. Philips also devised some multi-reflex structures, see [A](#), [B](#) and [C](#). The basic electrode arrangement of a reflex klystron is given below.

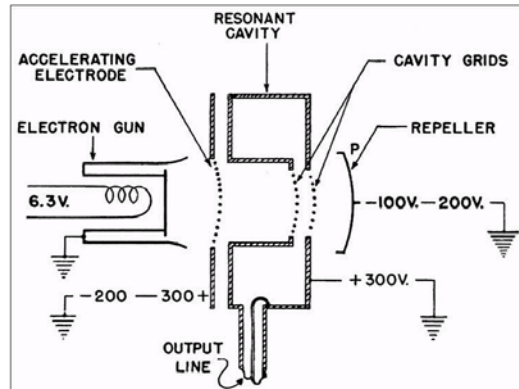


Fig. 1.6 – Draft of a reflex klystron structure, showing the repeller electrode and the single cavity with gap acting as buncher for electrons coming from the electron gun and as catcher for electrons pushed back by the repeller. Bunching occurs in the drift space, from the cavity to the vicinity of the repeller and back to resonator.

The first reflex klystron was the one designed in 1940 by Robert Sutton of the Signal School group at the Bristol University. Due to the name of its inventor, it was referred to as '[Sutton tube](#)'. Standardized as [NR89](#) or CV11, the 'Sutton tube' was the only device available as local oscillator for the receivers of microwave radar sets from September 1940 to the late 1941, when it was replaced by an improved EMI design. It was also copied by Rogers for Canadian REL and coded as Type 8. In the second half of 1941 even Western Electric introduced its low-voltage reflex klystron 707A.



Fig. 1.7 - The story of early British reflex klystron from summer 1940 to the end of 1941. A) An unbased early sample of '[Sutton tube](#)' likely built at the Bristol Signal School. B) A sample of [NR89](#), with the Air Ministry code 10E/501. C) In 1941 Rogers was asked by Canadian REL to design ruggedized copies of NR89 for its microwave radar sets. The [Type 8](#) is similar to the 'Sutton tube' with an aluminum shell and an improved tuner. D) At the end of 1941 EMI introduced an improved and more stable design which originated some frequency variants, as this [CV35](#). E) Knowing that Western Electric had introduced the [707A](#) low-voltage reflex klystron, in late 1941 TRE asked EMI for developing a similar device. This [10AL1](#) is an experimental prototype, built to evaluate a better coupling of the resonator to the electron beam and the generated noise. The design will lead in 1942 to the introduction of a new family, including among the others the [CV238](#), with meshes of corrugated tape brazed to the internal rim of the resonator discs.

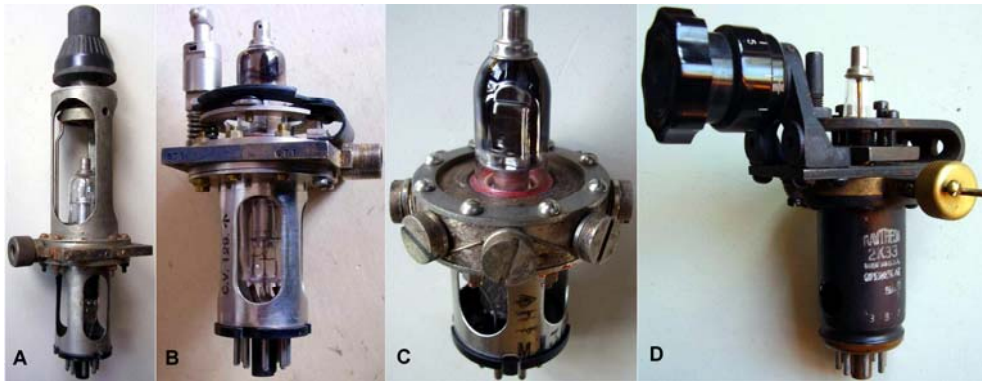


Fig. 1.8 - British reflex klystrons. A) [CV87](#) was the early EMI design for an X-band reflex klystron to be used as local oscillator. B) EMI [CV129](#) and its frequency variants, [CV217](#) or [CV224](#), were fitted with a more simple tuner. C) [CV238](#) was one of the frequency variants originated from the experiments on 10AL1, see 1.7E above. D) Actually [2K33](#) was manufactured by Raytheon but it was designed at Clarendon. Click to enlarge.

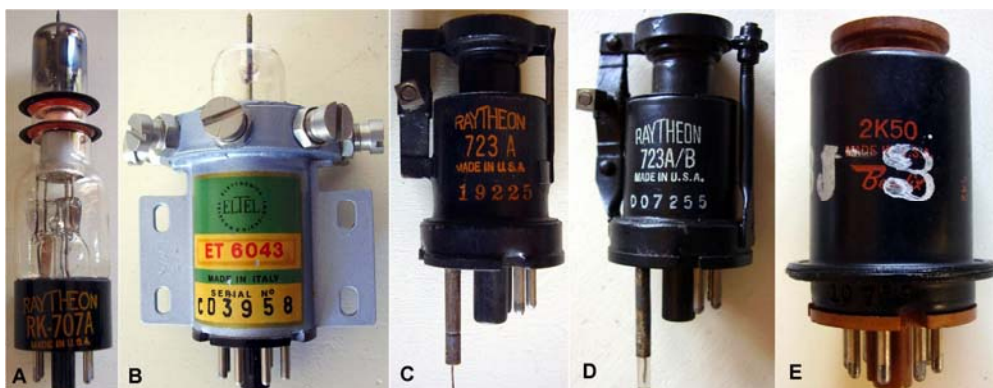


Fig. 1.9 - US reflex low-power klystron intended for use as local oscillator in radar receivers. A) [707A](#) was the first reflex klystron designed by Western Electric for the 10-cm band, Introduced in the second half of 1941, it was characterized by greater efficiency and stability against the British NR89, due to the reduced drift space and the better coupling of the gridded resonator gaps to the electron beam. B) Raytheon introduced a more compact and stable variant, the [2K28](#). It was followed by packaged types, complete of factory installed cavity, as the [OK85](#) and the [6043](#). In the photo a sample of ET 6043, license built by Italian EITel. C) [723A](#) was the first reflex klystron designed at Bell for the X-band. Tuning was accomplished by bows which compressed the upper part of the tube. Its design gave origin to countless frequency variants down to about 2 GHz. D) In [723A/B](#) tuning strut and bows were welded to the base collar, so to broaden the tuning range. 723A/B evolved in the registered [2K25](#), with tighter specifications. E) In the K-band [2K50](#) Bell used an electronic tuner. Waveguide output flange on the top. Click to enlarge.

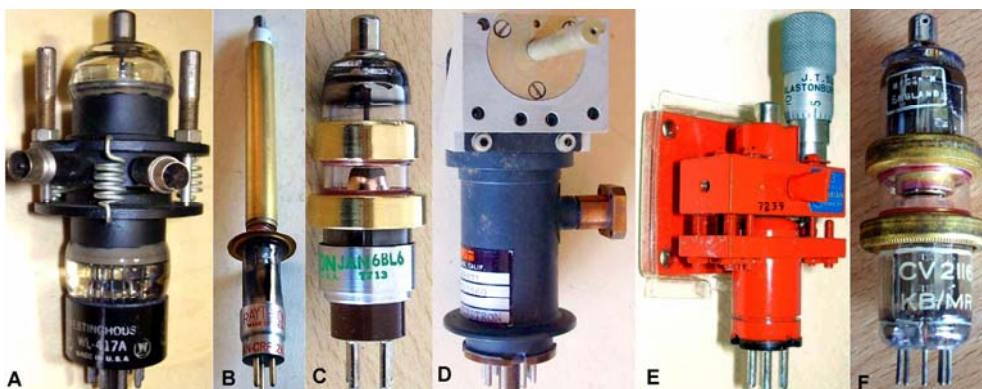


Fig. 1.10 - More reflex klystron tubes. A) [417A](#), registered as [2K41](#) was tunable around 3 GHz. B) [2K48](#) was designed by Western Electric to operate from 4.2 to 10.7 GHz. C) [6BL6](#) was widely used in signal generators, from 1.4 to 6.5 GHz. Sylvania also designed the companion [6BM6](#), tunable from 0.55 to 3.8 GHz. D) After the war EMI introduced a family of devices for millimetric waves. [R9521](#) in the photo was tunable from 35 to 40 GHz. E) Varian [X-13](#) was introduced as laboratory source for X-band microwave measurements. F) [CV2116](#) was a British version of the US 6BL6. Click to enlarge.