6.2 - Velocity Modulated Tubes: Klystrons

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Even if magnetron structures were described since the twenties, more serious investigation on velocity modulated or VM tubes started around the second half of the thirties, to overcome the severe frequency limitations due to the transit time of electrons in conventional space charge amplifiers. VM tubes include several families, differing from each other for their operating principle, or better for the way used by input port to exchange energy with electrons and back, from electrons to the output port. Basically they comprise Heil tubes, klystrons, magnetrons and traveling wave tubes, also known as TWTs.

6.2 - Klystron tubes

Klystron tubes appeared around the early days of WWII. In the article 'Klystron tubes' there are some notes about their structure and operation. Varian brothers are credited to have designed the early working prototypes at Stanford University from 1937 to 1939 for an aircraft blind landing system financed by Sperry. In the same days other investigations were in progress at least at Bell and in England as microwave power sources to be used in range detecting equipment, but quite soon magnetron tubes were preferred for the purpose. Klystron devices derived from the early designs were then mainly used through the war as local oscillators in microwave receivers, first at 10 cm, soon later in the X-band and then in the K-band. Just Sperry in America made a few medium power types for special applications and EMI in England made the high-power CV150. Anyway the development of high-power klystrons was only slightly delayed and soon after the end of the war their use became widely diffused in many fields, including UHF TV repeaters and LINACs.

The collection includes samples of the very early klystrons developed in England and in America, at Stanford and at Bell. Worth of note are the Sperry Prototype which can be dated around 1939, the British S-band 10E/501/NR89 'Sutton tube', also unbased and followed by CV35 and CV67, the Canadian REL type 8, the Bell design 707A available by the end 1941 and the British experimental prototype 10AL1. Moving to the X-band, we find samples of the very early 723A, of the improved 723A/B which was followed by the industry standard 2K25 and of the British types CV87, CV129 and CV217 and other frequency variants. Other interesting samples of early designs are the K-band 2K33A, developed by Raytheon starting from a British design, the electronically tuned WE equivalent, 2K50, and the linear beam 402A by Western Electric.

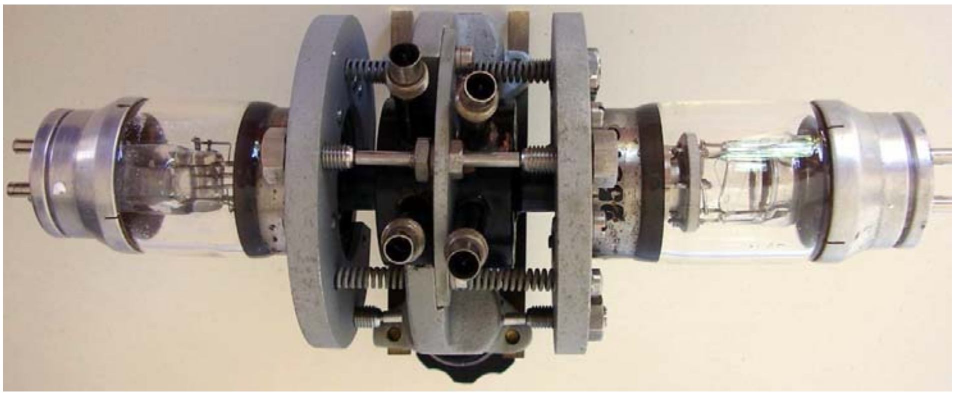

Fig. 6.2.1 - One of the very early klystrons manufactured at Sperry according to the design of Varian brothers, the Sperry prototype, about 1939. Probably intender for an experimental blind landing system. The sample is complete with its rare Type 11 tuner. (Click on image to enlarge)

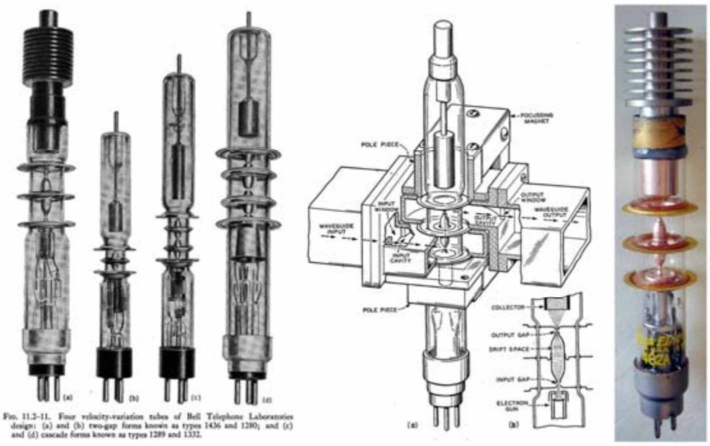

Fig. 6.2.2 -Developmental klystrons at Bell Telephone. Left, developmental klystrons, two two-gap, types 1436 and 1280 , and two cascade, 1289 and 1332. Center, cutaway view of the waveguide mount for a klystron amplifier. Right, derived from the 1436 prototype WE 402A was the only linear beam klystron from these types ever gone into production. (Click on image to enlarge)

Fig. 6.2.3 - British, Canadian and American klystrons used as local oscillators in the early S and X band radar sets. A) CV35 was one of the early British klystrons used since 1941 as local oscillator in S-band radar sets. It replaced the developmental type NR89 or 'Sutton tube' by the name of its designer. B) CV67 was a frequency variant of CV35. C) Canadian REL 8B was presumably derived from the NR89 Sutton tube, by adding a metal shield and a 4-pin base. D) The WE 707A was the very early American design of an S-band klystron in WWII. Its efficiency was quite poor and the grids became almost white in operation. D) 723A and the improved 723A/B were the early X-band reflex klystron desiged by Western Electric before the 2K25. (Click on image to enlarge)

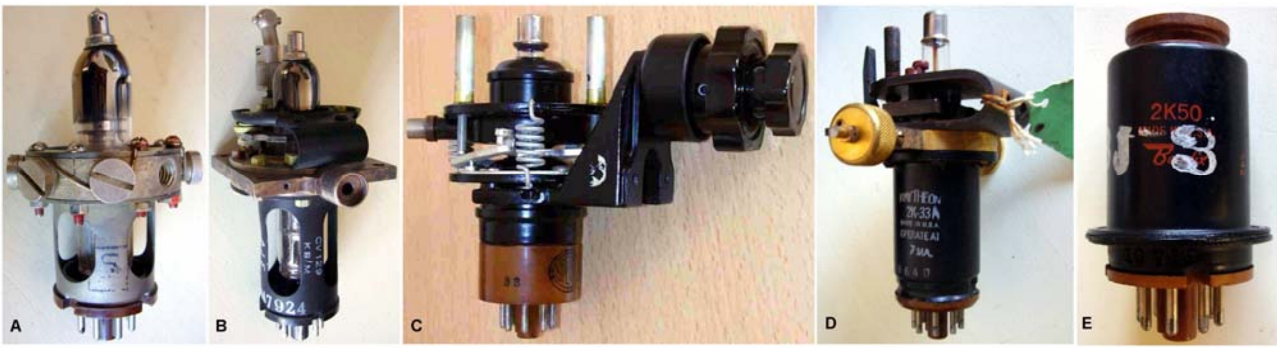

Fig. 6.2.4 - More klystron tubes developed during WWII. A) CV238, capable of operating at 250 volts, was introduced in 1943 to replace high voltage types, as CV35, in airborne applications. B) CV129, a British X-band klystron, was readily phased-out in favor of 723A/B. C) 2K41 was one of the many klystron devices designed by Sperry during the war. D) 2K33A, the first K-band klystron, was the result of a design performed in England at Clarendon and perfected in America by Raytheon. E) The electronically tuned 2K50 was the refined WE answer to 2K33. (Click on image to enlarge)

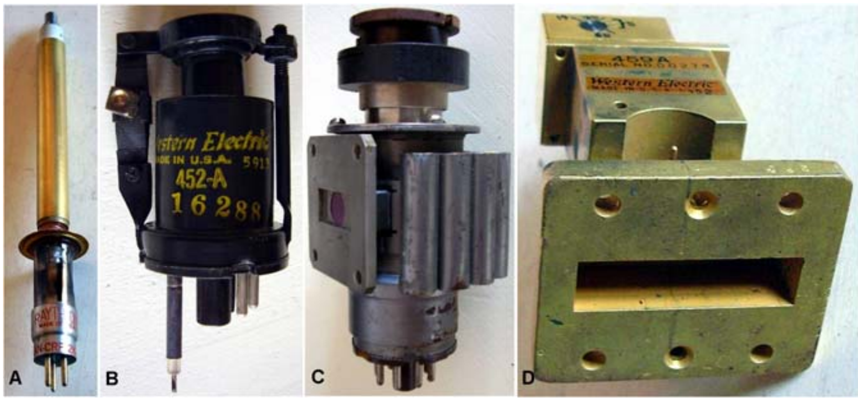

Fig. 6.2.5 - Western Electric klystrons. A) In the 2K48 the top grid was connected to a long tubular section, to be mounted in cavities tunable over wide ranges, from 4.2 to over than 10.5 GHz. B) 452A was one of the many frequency variants all based upon the design of 2K25. C) 445A was designed to operate around 11 GHz in the TJ microwave relay system. Also used as pump in the parametric amplifier of the NASA Echo radar which tracked the Moon around 1960. D) Vapor-phase-cooled 459A was used in microwave relay systems at 6 GHz. (Click on image to enlarge)

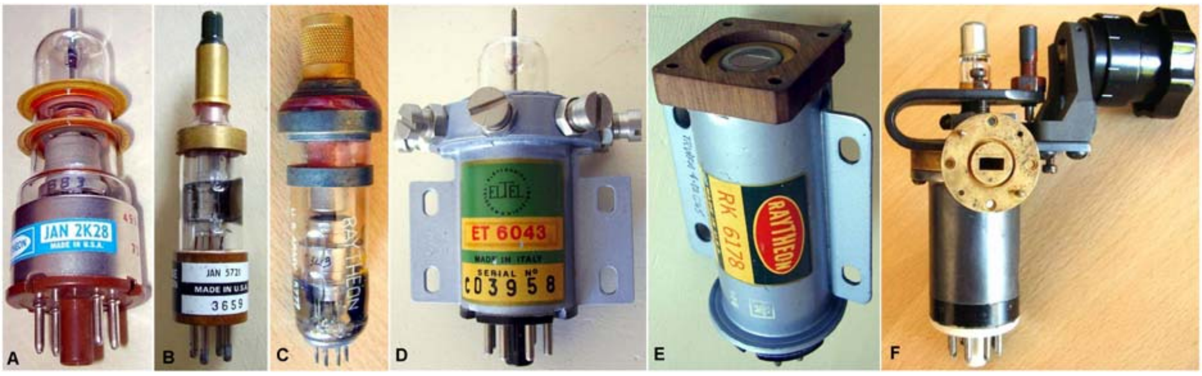

Fig. 6.2.6 - Raytheon was the largest supplier of microwave tubes during the war, retaining a leading role even later. A) 2K28 was registered in 1944 as improved version of the early 707A. B) 5721 was one of the many successive variants of a base model intended for wide band microwave signal generators. C) 5777 was modified to fit a custom tunable cavity in Polarad instrumentation. D) 6043 was a variant of 2K28 with factory installed cavity widely used in marine radars. This sample was made by Italian Eltel whose plant had been owned and fully qualified by Raytheon in the fifties, as ELSI acronym of Elettronica Sicula. E) 6178 was a top-flanged klystron operating around 15 GHz. F) One of the many derivatives of 2K33 operating over than 30 GHz, the QK290. (Click on image to enlarge)

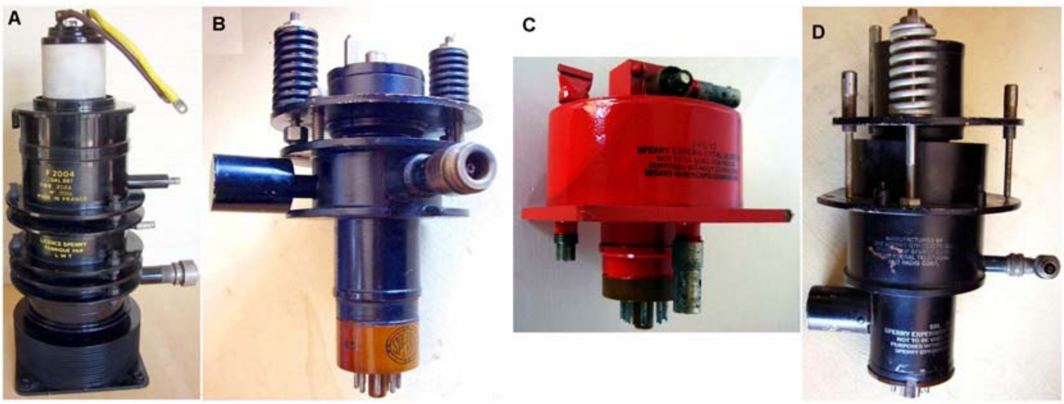

Fig. 6.2.7 - Sperry pioneered the use of klystron even before WWII as power generator for blind landing systems. In the years its production listed several power types. A) SAL89 was introduced in 1957 to generate 25 kW pulses for TACAN ground or shipboard installations. The above sample, dual marked as F-2004, was license built by French LMT. B) SRL-7C, early fifties, was rated for 5 to 10 W output power around 2 GHz. Electrostatic beam focusing. C) Sperry experimental SMC-11A was a frequency multiplier with an unusual 1 to 6 factor and 400 mW typical optput power. D) SRL-7H was rated for about 10 W output power at frequencies over than 2 GHz. (Click on image to enlarge)

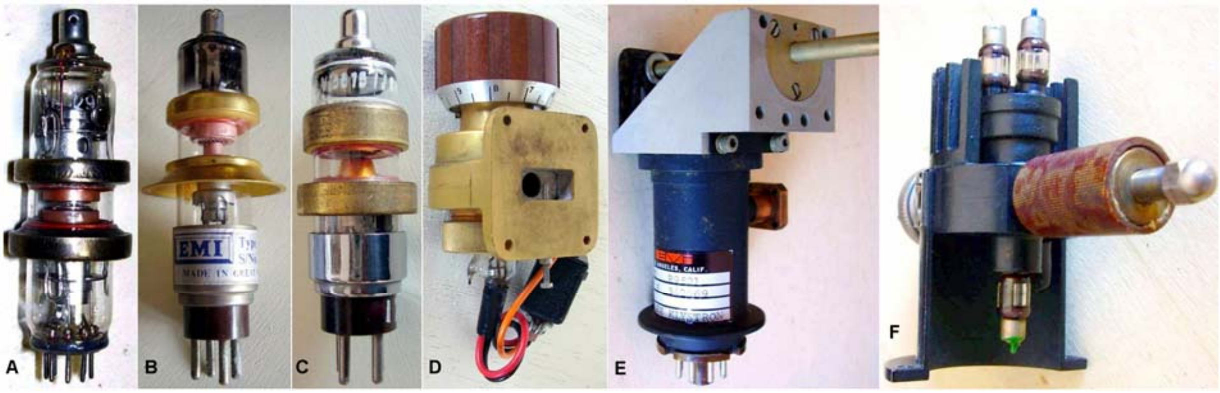

Fig. 6.2.8 - After the war British industry introduced countless klystron types, often jointly developed with some American firms or sold on the American market. One of the most active firm was EMI. A) VX5029 was the EMI prototype of CV2116. B) The experimental R9559, presumably prototype of CV6071, has a skirted flange to be mounted in some kind of special cavities. C) This EMI klystron approved as CV3615 was fully compatible with 6BM6 / 6BM6A. D) R9562 looks to be an X-band klystron, here mounted in a flanged cavity. E) R9521 was rated for 15 mW minimum output from 35 to 40 GHz. The label indicates an EMI/US, North Hollywood, CA, maybe just a sales office for musical and film products. By the way EMI was the acronym of Electro Musical Instruments. F) This undocumented 8RK8 was made by Elliot-Litton. (Click on image to enlarge)

The very unique klystron power oscillator of WWII

Fig. 6.2.9 - The collection includes a rare sample of Bitish EMI CV150, the only S-band power klystron intended to replace magnetrons as pulsed oscillator in airborne radar sets. Click on image to enlarge.

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