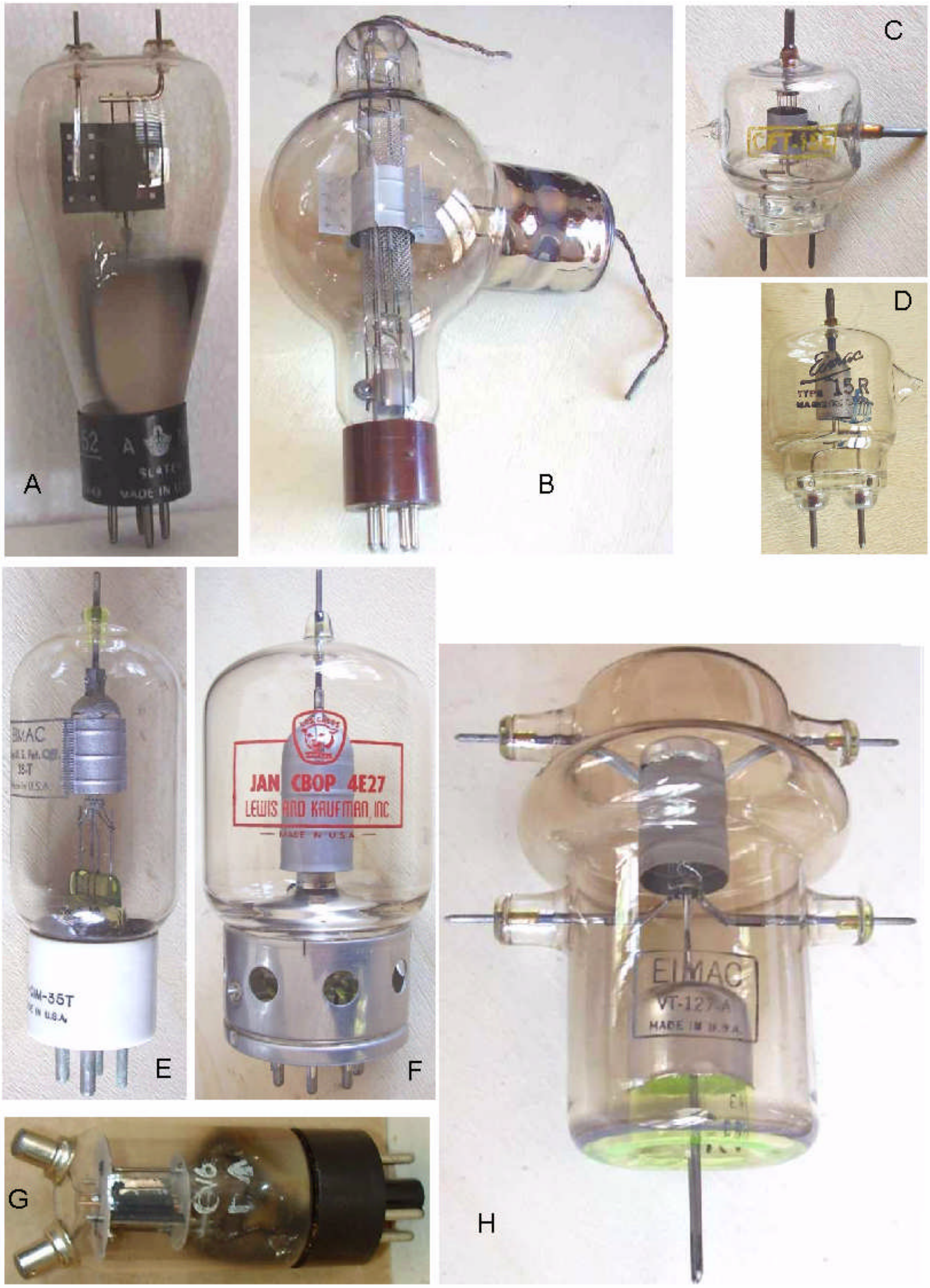
The road to high frequency tubes

Experimental works on UHF waves can be found in the second half of the nineteenth century: Heirich Hertz explored the UHF region well before the first vacuum tube could appear on the scene. In the ‘920s Barkhausen and Kurz made a triode oscillate at high frequency, with the grid positive, used as collector, and the anode negative, used as repeller, but the generated power was extremely low. The practical applications of high frequency waves, VHF and later UHF, had to wait until the ‘930s and the ‘940s, paralleled to the expansion of radio communications and of other applications, such as the radar. Probably the communication operators were the most active in promoting the early exploration of high frequencies and later in exploiting the results, moving everyday ahead the technological limits. Higher frequencies allowed wider bandwidth, making possible the transmission of several channels on a single link, highly directive, safely operating with very low power requirements. Nevertheless was the radar, on the breakthrough of the WWII, to suddenly accelerate the development of a wide variety of tubes of many and many dimensions and shapes, also operating according to unconventional principles in the VHF, UHF and up, well into to the microwave region.

Conventional vacuum tubes followed different roads, according to the knowledge of their time and to the specific requirements. In common tubes, the operation over 30MHz was adversely affected by several factors: interelectrode capacitance, lead inductance, unwanted resonance frequencies due to parasitic capacitance and inductance of internal structures, transit time of electrons. Every possible solution was thoroughly evaluated, sometimes leading to new families of tubes: acorn, mushroom, door-knob, lighthouse, oil-can, rocket, or generic disk-seal tubes, depending upon their power handling capabilities and frequency range, all found useful applications for years. Shapes characterized by well-spaced terminals became popular for a while. Scaled down electrode structures were proposed especially for small power tubes. New electrode designs, such as the squirrel-cage grid, and new materials were introduced to reduce the electrode spacing, and then the transit time. New circuital topologies were proposed to avoid internal feedback paths, such as the grounded grid amplifier tuned by means of bifilar or coaxial resonators; and new tubes, such as the planar or disc-seal types, were soon developed to match these circuits and grew in a variety of shapes and size.

Roughly over two decades, starting from the early ‘930s, the upper frequency limit of conventional vacuum tubes raised from about 30MHz to over than 5GHz. Later improvements, still in use at the end of the vacuum era, could be better defined as refinements, with materials selected for an increased and reliable life, such as the use of ceramics to replace glass.

The VHF road in convection cooled transmitting tubes



From early 930s to the eve of WWII there were continuous improvements in low power VHF transmitting tubes, intended for FM, early TV systems, radio relays and radar equipment. Solutions included short connections to grid and anode, baseless connections, special materials, as tantalum, for electrodes and hard glass bodies.

A: VT-62. B: GL-860, power tetrode. C: 15E, VHF triode, radar transmitter. D: 15R, diode, gridless 15E. E and F, 35T and 4E27, VHF transmitting tubes. G: CV6, one of the early tubes for VHF transceivers. H: VT-127, four used as ring oscillator in radar transmitters.

VHF Glass Power Tubes from '930s to '940s

In the '930s the frequency upper limit moved to VHF in many applications: FM communication and early FM broadcast, early television, radio relays and radar equipment asked for high operating frequencies and new tubes soon appeared.
VT62, around 1936, was the British version of 834, 50W at 100MHz. 808 could be operated up to about 60MHz. 860 tetrode, top right, was introduced in 1929; operation up to 60MHz possible. 35T was introduced in the early '40s; 100MHz. 15E, also known as 4C30, was used in the ring oscillator of ABS radar at 500MHz. 388, capable of oscillation at 900MHz, was used in 1A prewar altimeter. 8025 was capable of 40W plate dissipation, operating at 500MHz; WWII. 100TH was usable up to about 60MHz.

External Anode Power Tubes
British 4H-182E and CV28


Here two British made power transmitting tubes. 4H-162E, on top, is rated for 500W anode dissipation with forced air cooling. CV28, bottom, requires external radiator. It is capable of 1.2KW anode power dissipation.

General Electric GL-434-A and GL-6019

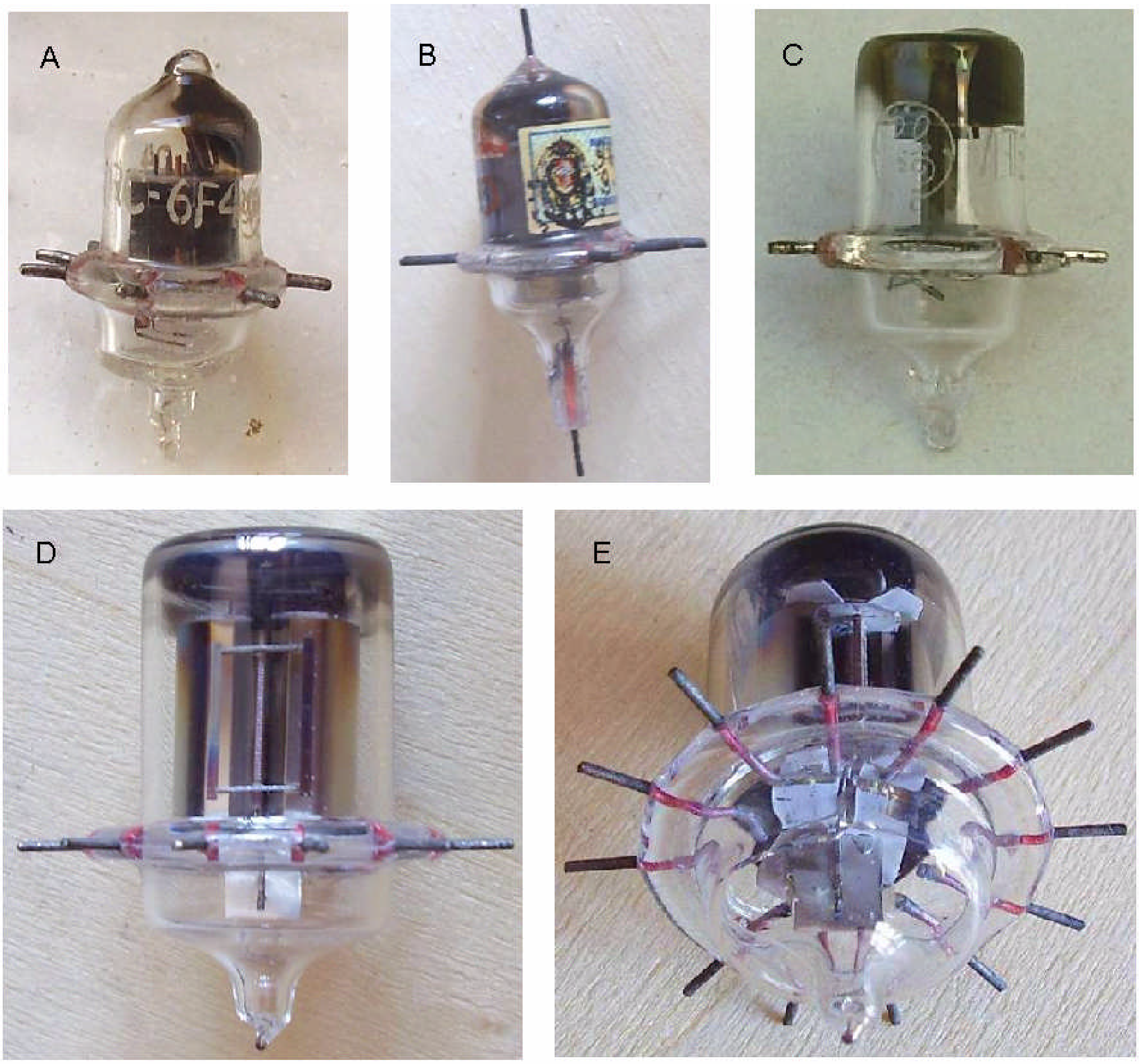
Two transmitting tubes from General Electric. GL-434-A was used in early radar applications. The coaxial tetrode GL-6019 delivers 1KW output at 900MHz. Water cooled, it was intended for UHF TV transmitters.

Amperex 6076 – QBL5/3500

6076 is a forced air cooled transmitting tetrode. 3.5KW, 220MHz. Intended for FM-TV transmitters.

A mix of small power tubes, Pa under 200W

Acorn Tubes



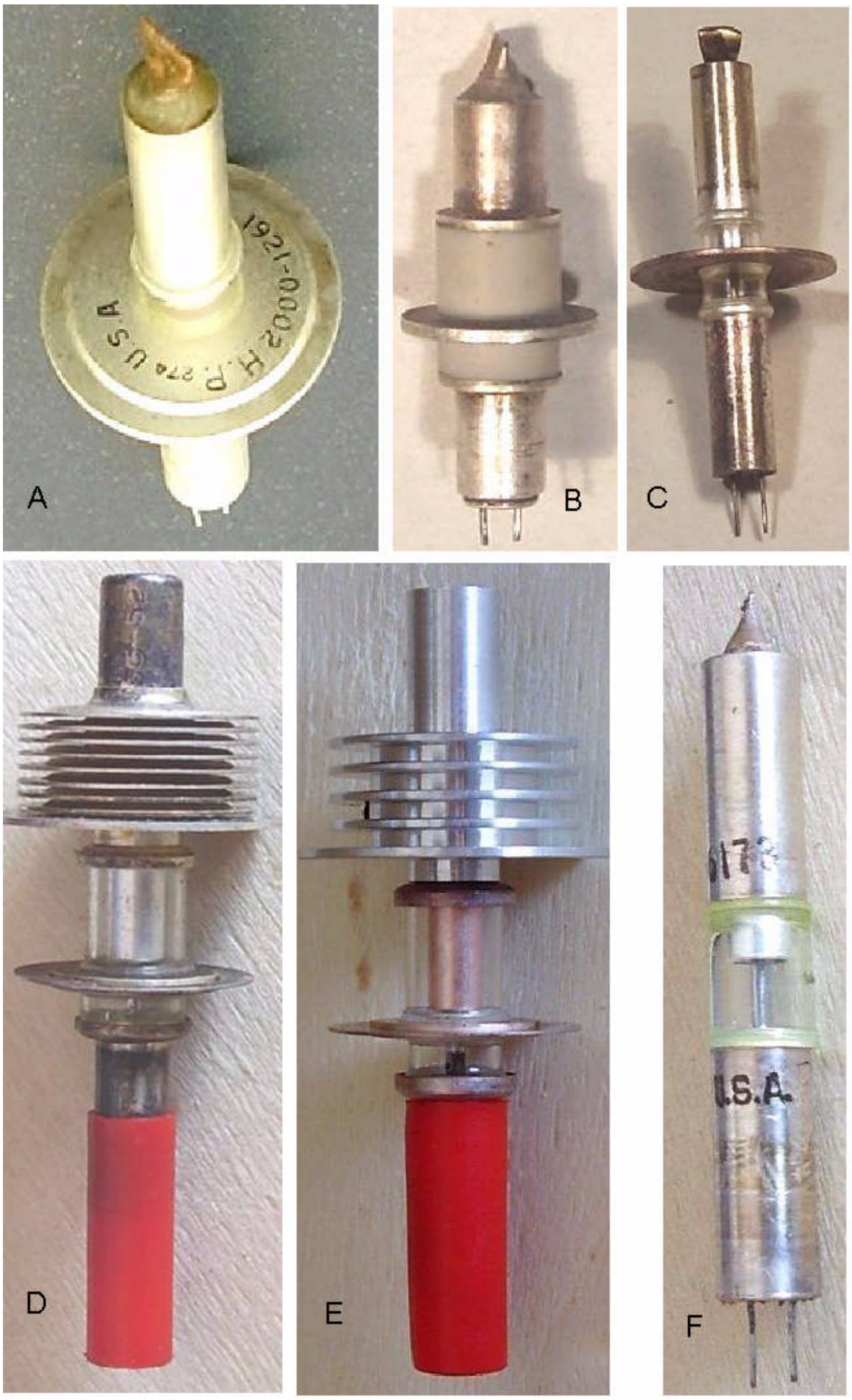
Acorn tubes were introduced around the mid 930s to reduce parasitic parameters, inductance and capacitance, of the connections. Pins went out radially from the glass press around the body and sometimes from the top and from the bottom. When the miniature 7 pin bulbs appeared, the small electrode structures of the acorn tubes were readily moved to the new envelope, without appreciable decrease in high frequency performances.

UHF Glass Disc-Sealed Tubes

Operation in the UHF region around 1GHz and over required close spacing of electrodes: planar structures were simple enough to produce, once defined a reliable process of soldering the glass spacers, used in the early '940s, to electrode copper surfaces. Several shapes were designed depending upon the anode power dissipation and the mechanical interface to the external cavities. Useful frequency up to about 3GHz.

A, B: two lighthouse tubes, power around 5W. C, D: two pencil tubes, the one at full right is a signal diode; power is in the order of very few watts. E: early integral radiator power tube; 125W, 1.4GHz. F, G: oil-can shape could dissipate about one hundred watts, due to the anode radiator; G is a diode. H, I: rocket shape for low power oscillators or signal amplifiers.

UHF Pencil Low-Power Tubes



High frequency tubes asked for little interelectrode spacing: planar structures made easy the assembling of electrodes close to each other, with tight tolerances. Pencil tubes were low power devices, useful up to about 3GHz. As usual, in the years appeared several variants, such as devices with ceramic spacers or with integral anode radiator. Pencil tubes were first introduced by RCA and second sourced by other manufacturers, as Sylvania or Tung-Sol. RCA also offered factory assembled modules, with the tube already mounted into the tuned cavity.

A: 4043 RCA, 5W at 500MHz. **B:** 4062A RCA, cermet triode, 10W, 4GHz. **C:** 5675, 5W, 1.7GHz. **D** and **E:** 6263 and 6263A, 8W, 500MHz. **F:** 6173, UHF pencil diode, 3.3GHz.

UHF oil-can shape tubes

Oil-can tubes were introduced as a variant of planar tubes, to increase anode power dissipation. The anode is large and has either an integral radiator or a conductive surface to be mounted in some external cooler. Power dissipation in the order of 100W, with operating frequencies up to about 3GHz were available.

GE UHF cermet low-power tubes

GE offered the most advanced and complete line of low power cermet tubes, usable as amplifiers or oscillators at frequencies up to 10GHz; also available factory assembled modules, based on these tubes. The tubes were very small, typically 1 to 2.5 cm. Flat electrodes and ceramic spacers were used to ensure uniform spacing. A: 6299, μ 110, 3GHz. B: 7077, μ 90; used in Pioneer III space probe. C, H: 7462, lugged variant of 7077. D: 7486, variant of 7077 for use as amplifier or oscillator. E,F: 7391, 65mW at 5.4GHz as oscillator. J: Y1610, 7.5GHz oscillator. K and M: two MCMs, Microwave Circuit Modules, using tubes similar to the J one.

GE UHF modules