Traveling Wave Tube

Traveling wave tubes (twt) are wideband amplifiers. They take therefore a special position under the velocity-modulated tubes. On reason of the special low-noise characteristic often they are in use as an active RF amplifier element in receivers additional. There are two different groups of twt:

- low-power twt for receivers

  occurs as a highly sensitive, low-noise and wideband amplifier in radar equipments

- high-power twt for transmitters

  these are in use as a pre-amplifier for high-power transmitters.

Furthermore they are introduced to:

Figure 2. Russian low-power twt UV-1B (cyrillic: УВ-1Б)

- Physical construction and functional describing
- Characteristics of a twt
  twt's poweramplification
  twt's bandwith

Physical construction and functional describing

The Traveling Wave Tube (twt) is a high-gain, low-noise, wide-bandwidth microwave amplifier. It is capable of gains greater than 40 dB with bandwidths exceeding an octave. (A bandwidth of 1 octave is one in which the upper frequency is twice the lower frequency.) Traveling-wave tubes have been designed for frequencies as low as 300 megahertz and as high as 50 gigahertz. The twt is primarily a voltage amplifier. The wide-bandwidth and low-noise characteristics make the twt ideal for use as an rf amplifier in microwave equipment.

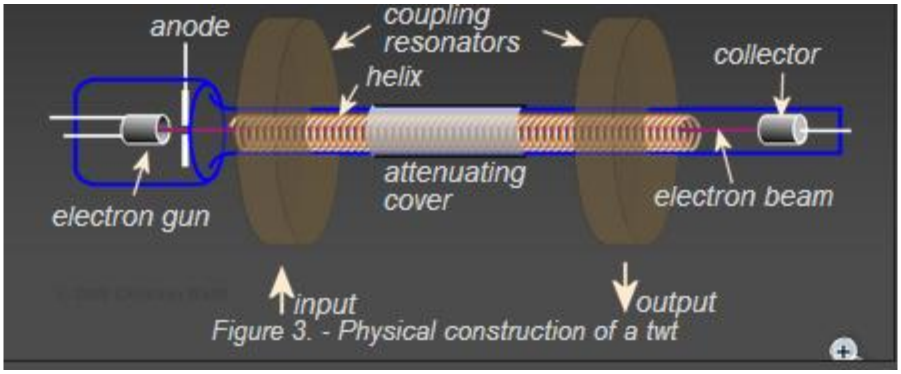

Figure 3. - Physical construction of a twt

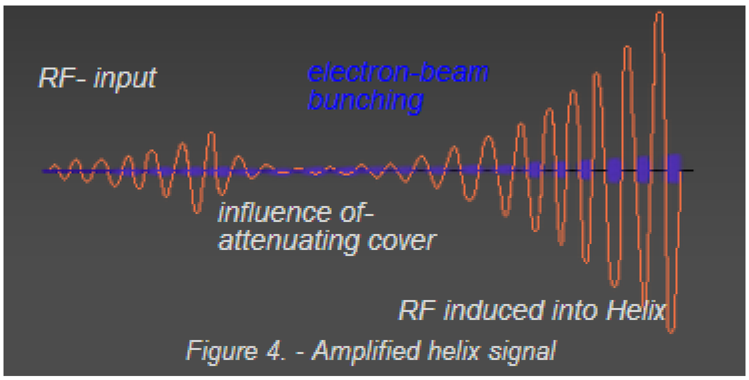

Figure 4. - Amplified helix signal

The physical construction of a typical twt is shown in figure 3. The twt contains an electron gun which produces and then accelerates an electron beam along the axis of the tube. The surrounding magnet provides a magnetic field along the axis of the tube to focus the electrons into a tight beam. The helix, at the center of the tube, is a coiled wire that provides a low-impedance transmission line for the rf energy within the tube. The rf input and output are coupled onto and removed from the helix by waveguide directional couplers that have no physical connection to the helix. The attenuator prevents any reflected waves from traveling back down the helix.

The following figure shows the electric fields that are parallel to the electron

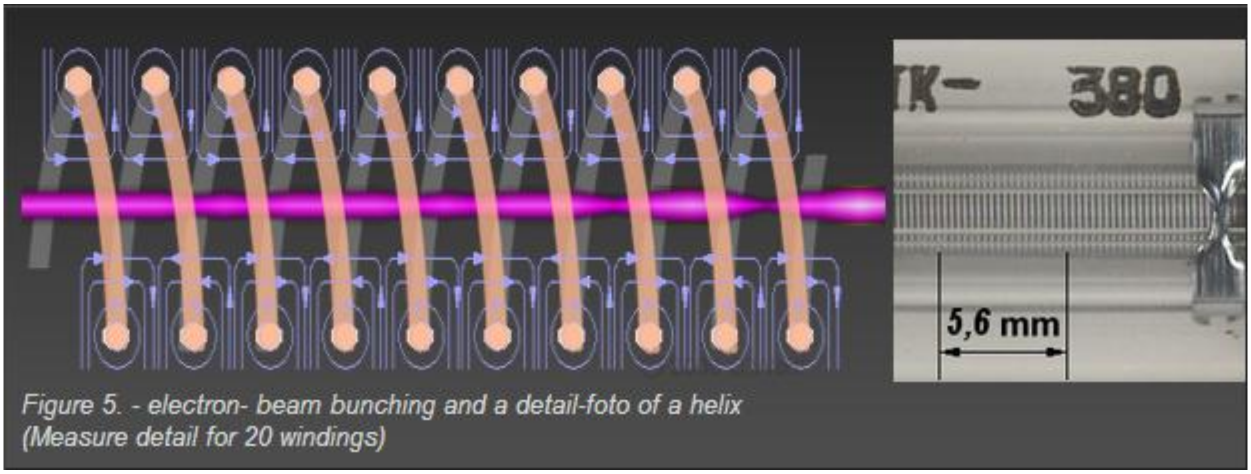

Figure 5. - electron- beam bunching and a detail-foto of a helix
(Measure detail for 20 windings)

Figure 5. - electron- beam bunching and a detail-foto of a helix

(Measure detail for 20 windings)

The electron- beam bunching already starts at the beginning of the helix and reaches its highest expression on the end of the helix. If the electrons of the beam were accelerated to travel faster than the waves traveling on the wire, bunching would occur through the effect of velocity modulation. Velocity modulation would be caused by the interaction between the traveling-wave fields and the electron beam. Bunching would cause the electrons to give up energy to the traveling wave if the fields were of the correct polarity to slow down the bunches. The energy from the bunches would increase the amplitude of the traveling wave in a progressive action that would take place all along the length of the twt.

Characteristics of a twt

The attainable power-amplification are essentially dependent on the following factors:

constructive details (e.g. length of the helix)

electron beam diameter (adjustable by the density of the focussing magnetic field)

power input (see figure 6)

voltage UA2 on the helix

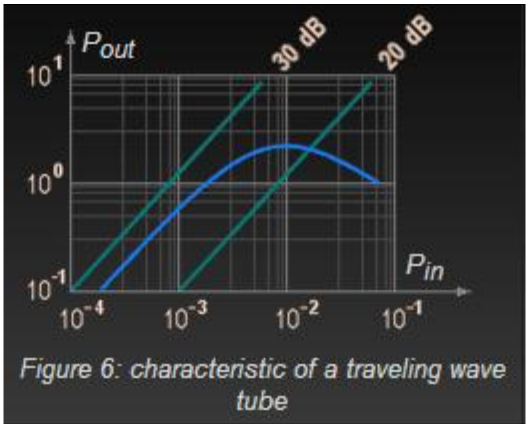

Figure 6: characteristic of a traveling wave tube

As shown in the figure 6, the gain of the twt has got a linear characteristic of about 26 dB at small input power. If you increase the input power, the output power doesn't increase for the same gain. So you can prevent an oversteer of e.g the following mixer stage. The relatively low efficiency of the twt partially offsets the advantages of high gain and wide bandwidth.

Given that the gain of an twt effect by the electrons of the beam that interact with the electric fields on the delay structure, the frequency behaviour of the helix is responsible for the gain. The bandwidth of commonly used twt can achieve values of many gigahertzes. The noise figure of recently used twt is 3 ... 10 dB.

The helix may be replaced by some other slow wave structure such as a ring-bar, ring loop, or coupled cavity structure. The structure is chosen to give the characteristic appropriate to the desired gain/bandwidth and power characteristics.

Ring-Loop TWT

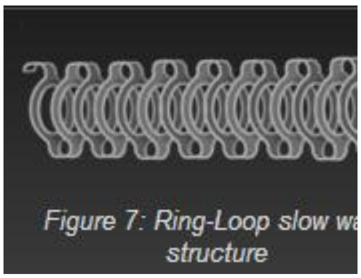

Figure 7: Ring-Loop slow wave structure

A Ring Loop TWT uses loops as slow wave structure to tie the rings together. These devices are capable of higher power levels than conventional helix TWTs, but have significantly less bandwidth of 5…15 percent and lower cut-off frequency of 18 GHz.

The feature of the ring-loop slow wave structure is high coupling impedance and low harmonic wave components. Therefore ring-loop traveling wave tube has advantages of high gain (40…60 Decibels), small dimension, higher operating voltage and less danger of the backward wave oscillation.

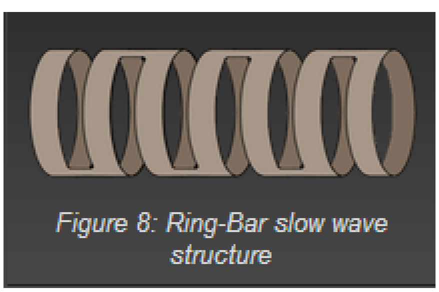

Figure 8: Ring-Bar slow wave structure

Ring-Bar TWT

The Ring-Bar TWT has got characteristics likely the Ring-Loop TWT. The slow wave structure can be made easier by cut-out the structure of a copper tube.

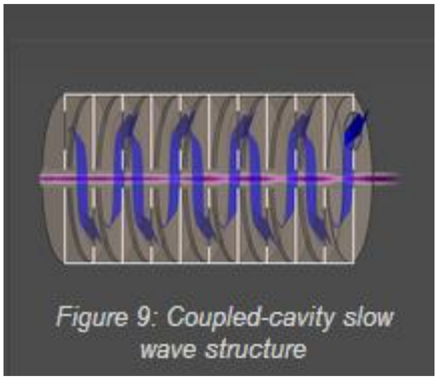

Figure 9: Coupled-cavity slow wave structure

Coupled-cavity TWT

The Coupled-cavity TWT uses a slow wave structure of a series of cavities coupled to one another. The resonant cavities are coupled together with a transmission line. The electron beam (shown in figure 9 as red beam) is velocity modulated by an RF input signal at the first resonant cavity. This RF energy (displayed as blue arrow) travels along the cavities and induces RF voltages in each subsequent cavity.

If the spacing of the cavities is correctly adjusted, the voltages at each cavity induced by the modulated beam are in phase and travel along the transmission line to the output, with an additive effect, so that the output power is much greater than the power input.

Source: http://www.radartutorial.eu/08.transmitters/Traveling%20Wave%20Tube.en.html