Folded wave guide TWT for 92 – 95 GHz band outdoor wireless frontend

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INTRODUCTION

The Horizon 2020 TWEETHER project aims to a breakthrough for the new generation of high data rate wireless networks, introducing for the first time millimeter wave traveling wave tubes (TWTs) as enabling devices. TWT is the only device able to provide adequate transmission power for wireless distribution of the internet signal in a wide area. The frequency range 92 – 95 GHz is a light licensed portion of the spectrum, with about 3 GHz available bandwidth for point to multi point distribution. However, the millimetre wave frequency range poses formidable challenges for design and fabrication of TWTs with low cost and long lifetime, suitable for the wireless market.

The paper will describe the design and the fabrication challenges to achieve the required 40W output power in 92 -95 GHz frequency band.

BACKGROUND

The portion of the spectrum above 40 GHz is still not fully exploited for wireless communications. A number of wireless systems limited to Point to Point (PtP) links are available at V-band (centered at 60 GHz) and E-band (71-86 GHz). High gain antennas are required due to the lack transmission power. The sub-6GHz band is congested and cannot support further traffic increase. In contrast, the need to increase the throughput will be addressed by an increase of cell density will require a capillary backhaul. The fiber has been demonstrated too expensive for the purpose, therefore a wireless solution is preferred. The region of the spectrum below 100 GHz offers a number of wide sub-bands able to support multigigabit data transmission, but most of them are regulated for PtP. Further, this portion of the spectrum suffers substantially higher attenuation in comparison to the microwaves.

The available front ends are based on solid state amplifiers with limited power at millimeter waves, typically below one Watt.

The TWEETHER project [1 -3] aims to a breakthrough in wireless network for high capacity distribution at W-band (92 – 95 GHz) by enabling a Point to multipoint distribution to cover a wide area as the actual microwaves system. Low gain antennas are used to cover wide sectors of the region to serve.

A Traveling Wave Tube (TWT) at W-band is the enabling device for a high capacity density to provide backhaul to the new high density cell networks.

W-BAND TWT

The TWT is a vacuum electron device with wide band amplifying properties [4]. The working mechanisms is based on the interaction of an energetic electron beam with an electric field propagating in a delay line to synchronize the phase velocity of the wave with the speed of the electrons. The process permits a relevant transfer of energy from the electron beam to the electric field and consequently high output power in a wide frequency band.
The TWT has a three dimensional mechanical structure that requires advanced fabrication technologies.
In particular, the Slow Wave Structure, presents substantial fabrication challenges due to the short wavelength at 94 GHz.
The folded waveguide [5] is a slow wave structure based on a serpentine with a beam tunnel in the longitudinal dimensions. The propagating field is always in phase with the electron velocity in correspondence of the beam tunnel. The FWG is a very promising SWS for the relatively easy fabrication, simple and robust structure and effective coupling.

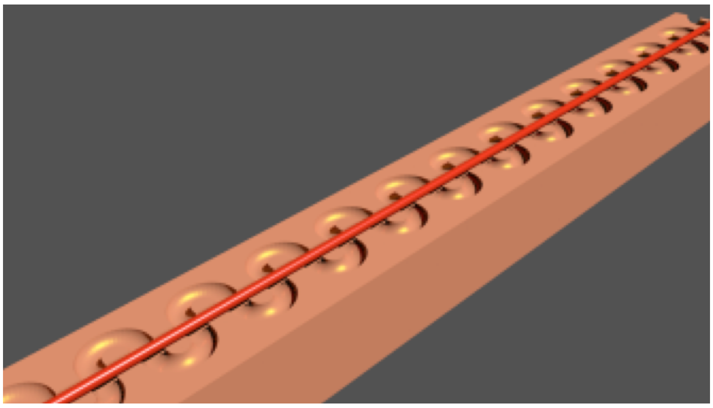

Fig.1 Rendering of a folded waveguide with the beam

The main challenge at W-band is to design and realize a TWT with low cost, adequate performance for the system specifications and of easy fabrication and assembly.

The specifications for the TWEETHER TWT are 40W saturated power and 40 dB gain. The small dimensions of the parts, due to the high frequency range, required an accurate design to optimize the performance compliant with the capabilities of the fabrication process. A specific campaign of particle in cell simulations using both CST-PS and MAGIC-3D was carried out to optimize the beam / wave interaction and achieve the specification targets. Presently, the TWT is in advanced fabrication stage. The folded waveguide is coupled with an output flange WR10.

The beam optics is based on a conventional Pierce gun to generate a cylindrical electron beam. The beam voltage is 16 kV and the beam current is 70mA. This permits to use a magnetic focusing field in the order of 0.3 T.

The simulation of the beam optics provided an excellent beam confinement (Fig.1).

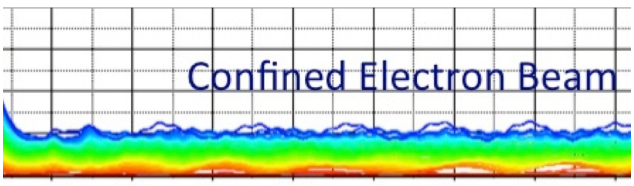

Fig. 1 Simulation of the beam transmission

The output power was simulated in the whole bandwidth, with two different reduced conductivities of copper (σ_c) with respect to the theoretical value of $5.7 \cdot 10^7$ S/m, to keep into account a not perfect metal surface finishing. In both the cases the TWT satisfies the 40W specification in the 92-95 GHz range as shown in Fig. 2. The results in Fig. 2 are achieved considering the worst case of σ_c=$2.9 \cdot 10^7$ S/m. An output power higher than 40 W and a gain of about 40 dB is obtained. The gain and the output power are a function of the number of periods. A wide range of performance can be obtained by modifying the nominal dimensions.

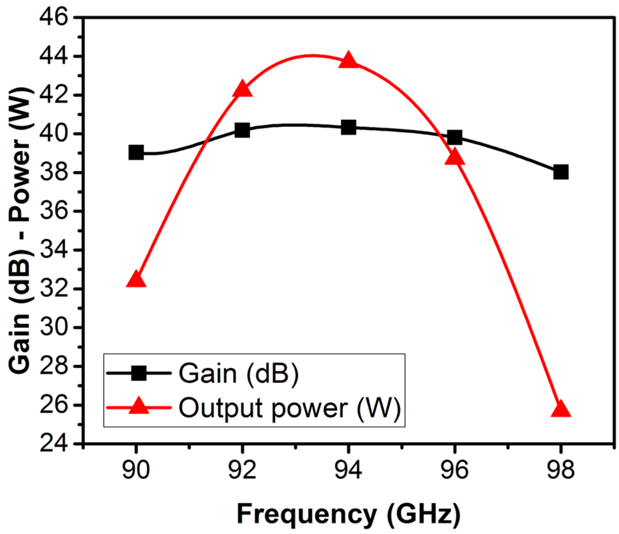

Fig. 2 Gain and output power of the TWT for a copper conductivity of $2.9 \cdot 10^7$ S/m

The fabrication of the folded waveguide was performed by high accuracy CNC milling machine (Fig.3). HCOF (High Conductivity Oxygen Free) copper was used. The calibration of the CNC milling process has permitted to obtain a very precise fabrication and low surface roughness. The detail of the bend is shown in Fig. 4. It is notable the quality of the surfaces. The conductivity of the metal is substantially improved by a low surface roughness.

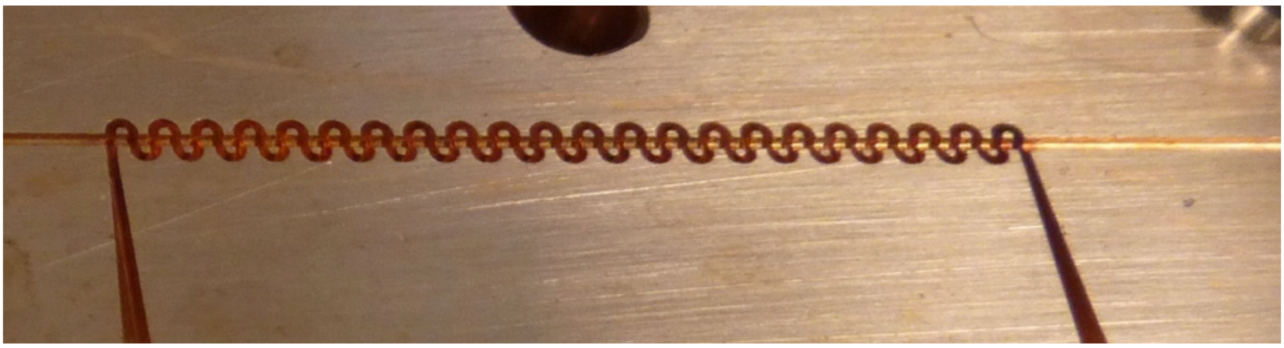

Fig. 3 Detail of the microfabricated Folded Waveguide in the 92 – 95 frequency range with the coupling and the beam channel.

CONCLUSIONS

A W-band TWT based on a folded waveguide is in advanced fabrication status. The high quality of the mechanical microfabrication assures performance at the state of the art. The availability of the W-band TWT will open new perspectives for wireless communications, both terrestrial and satellite.

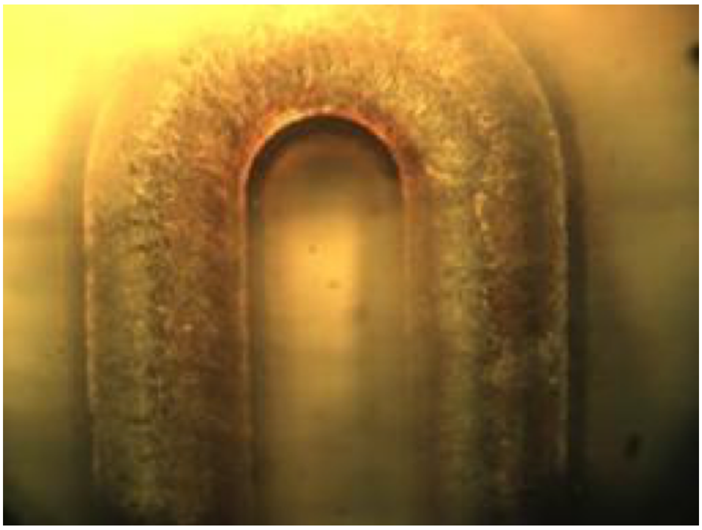

Fig. 4 Detail of the surface of the bend of the folded waveguide

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