D-band Transmission Hub for Point to MultiPoint Wireless Distribution

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***Abstract* — The first Transmission Hub for Point to multipoint wireless distribution at D-band (141 – 148.5 GHz) is presented. The paper reports the development of the main components of the transmission hub, including MMIC chipset, TWT, Image rejection filter and horn antennas.**

***Keywords* — D-band, wireless, transmission hub, MMIC, TWT, filter, antennas.**

The exploitation of the spectrum above 100 GHz for wireless communications strongly depends on availability of affordable front end and adequate transmission power to overcome the high rain attenuation that affect most of the region of the globe. While point to point links below 90 GHz are available in the market and have been tested up to 200 GHz with very high gain antennas, no point to multipoint system is presently available [1 - 6]. Point to multipoint systems that are common at microwave, at the increase of the frequency are difficult to implement [7 - 10]. The use of low gain antennas for producing a wide beam needs much higher transmission power and amplification gain (not less that 15 - 20 dB, assuming antennas with 15 - 25 dBi gain for beam up to 90 degrees wide).

However, the wide available band above 100 GHz, e.g. D-band (141-174.8) has available 27 GHz, offers new opportunities for high capacity wireless transmission. The D-band allows to distribute tens gigabit per second, that can be translated in area capacity of hundreds of Gb/s per kilometre squares. The growing traffic predictions need the deployment of high density of small cell to provide those level of data [11, 12].

The paper presents the design and development of the first Transmission Hub for Point to multipoint wireless distribution at D-band (141 – 148.5 GHz). The Transmission Hub is developed in the frame of the European Commission H2020 ULTRAWAVE [13, 14].

I. Electronics for D-band Transmission Hub

A. Topology

The Transmission Hub is the core of the Point to MultiPoint D-band wireless system. It permits to distribute high data rate on a wide sectorial area illuminated by the low gain antenna. The schematic of the Transmission. Hub is shown in Fig. 1. It consists of a transmitter and receiver at D-band, two intermediate frequency levels of up-conversion and down-conversion are used to connect to the modem in C-band. The first IF level is with the LO (Local Oscillator) at W-band (92 GHz) to convert from D-band to Q-band. The second IF level is with the LO at low Q-band (46 – 47.3 GHz) to convert to C-band. The D-band section includes two MMIC power amplifiers in the transmission chain. The medium power amplifier (mPA) and the Power Amplifiers (PA). It also includes a Low Noise Amplifier. The traveling wave tubes provides the transmission power for satisfying the coverage specifications [15 – 16].

B. X4 Frequency multiplier

A custom X4 active frequency multiplier (FM, Fig. 2) has been introduced during the system architecture assessment phase, to serve as the local oscillator signal for D-band mixers (the upconverter microphotograph is plotted in Fig.3). The frequency multiplier accepts as input a 23.3 GHz signal and multiplies it by 4, synthesizing a 94 GHz signal, as required by the mixer. This is accomplished through the cascade of two x2 multipliers and intermediate/final amplifying buffer stages, resulting in an overall multiplier gain in the range 3-5 dB all over the output frequency range. Dynamic specifications require an output power level of at least 5 dBm at 94 GHz, corresponding to a source power level of 5 dBm. The technological design process chosen for the x4 FM MMIC realization is the D01MH provided by OMMIC. The

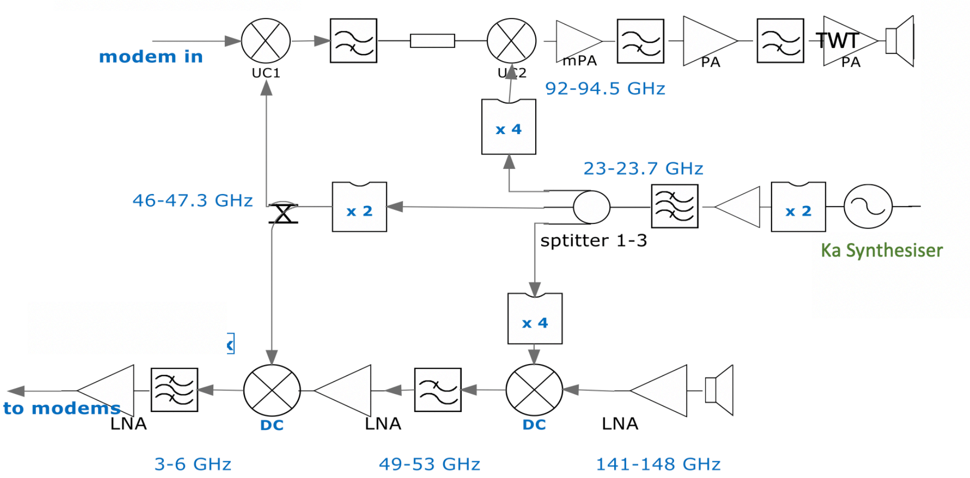


Fig. 1 Transmission Hub schematic

Table I Chipset specifications D band transceiver

	Frequencies GHz	G (Losses) dB	P1in dBm	P1out dBm	LO level dBm	S Parameters & Isolation
Up & down mixer	IF 49 - 54*; LO 92 - 95; RF 141 - 148.5	-11	-5		6	LO leakage. <-8dB/RF
Power Amplifier	141 - 148.5	14	5	19		S_{11}, S_{22} <9dB
Medium Power A	141 - 148.5	10	5	10		S_{11}, S_{22} <9dB
X4 Multiplier	in 23 - 24; out 92 - 96	0 - 1	6	5	6	25 dBc/f_0
LNA	141-148.5	20	NF 5.5dB			

technology is a metamorphic GaAs-based and a channel length of 0.125 µm. The process is featured by a f_t and a f_{max} of 150 GHz and 250 GHz respectively. Typical values of power density and g_m are 300 mW/mm and 700 mS/mm respectively. Measured performance of a typical multiplier die are plotted in Fig. 4, resulting in approximately 7 dBm all over the output frequency range.

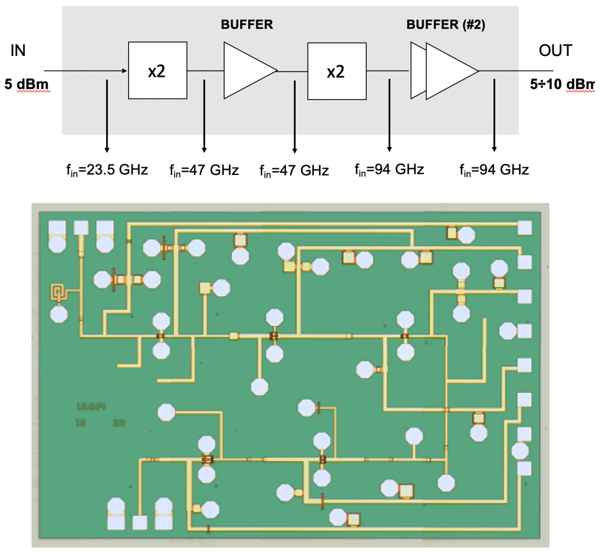


Fig. 2 X4 Frequency multiplier

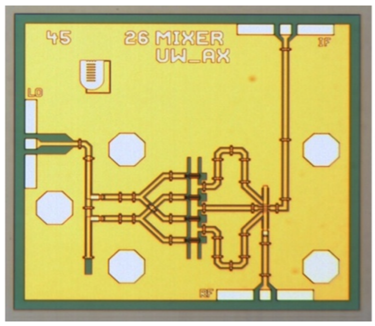


Fig. 3 D-band Upconverting mixer

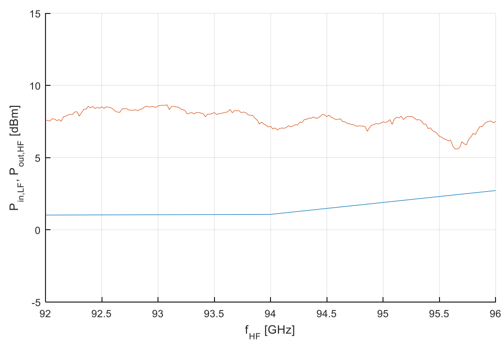
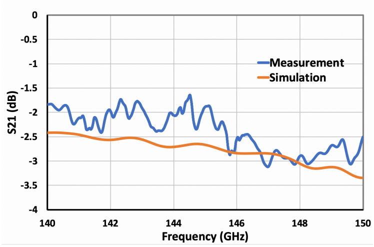


Fig. 4 Power output of the X4 frequency multiplier

C. D-band Traveling Wave Tube

A novel D-band TWT has been designed and is in fabrication phase. It provides 12 W saturated output power in the whole frequency band. All the parts where built and the final assembly is in progress. The interaction structure has been successfully measured demonstrating a wide bandwidth (Fig. 5). The TWT will provide about 12 W and 35 dB gain. The output power is about two orders of magnitude higher than the best solid-state power amplifier at the same frequency.



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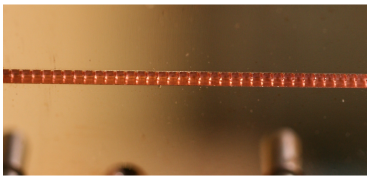
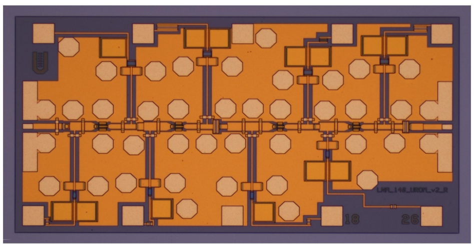


b)

Fig. 5 D-band double corrugated waveguide a) S_{21} b) fabrication

D. Low Noise Amplifier

The Low Noise Amplifier (LNA) of the chipset, designed to operate over the 141-148 GHz band, is realised making use of the advanced OMMIC 40nm mHEMT technology [17]. The four-stage architecture is implemented in GCPW, as visible from the microphotograph in Fig. 6. Resulting measured performance include approximately 20 dB gain and 5.1 dB noise figure over the desired bandwidth.



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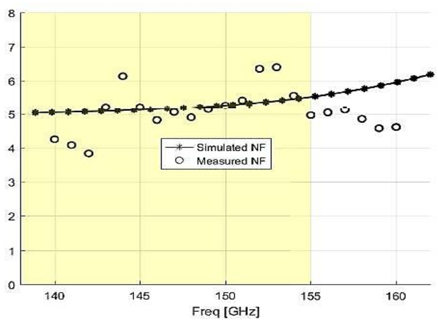

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Fig. 6 a) Photograph of LNA, b) Noise Figure measurements

E. D-band medium power amplifier (MPA)

The chip photograph of the realized D-band medium power amplifier (MPA) as shown in Fig. 7. The medium power amplifier (MPA) is fabricated at the Ferdinand-Braun Institute (FBH), Berlin, in a monolithic transferred-substrate (TS) InP-DHBT process. The InP transistors are transferred and bonded to a Si substrate in a wafer-level bonding process using benzocyclobutene (BCB). The InP DHBTs have 0.8 µm wide emitters and achieve f_t and f_{max} values of about 350 GHz with BVCEO = 4 V. The BCB stack above the Si substrate includes three gold metal layers (G1, GD , G2) with 2 µm, 2.5 µm, and 4.5 µm thickness, respectively, MIM capacitors with a sheet capacitance of 0.3 fF/µm² and NiCr thin film resistors (sheet resistance of 25 Ω/sq). The MPA consists of a driver stage with a 2 way combined unit cell power amplifiers (PA). A unit cell power amplifier is designed of a single finger driver stage with a 2 fingers power stage. In order to achieve small signal gain more than 10, the stages are biased in class A condition.

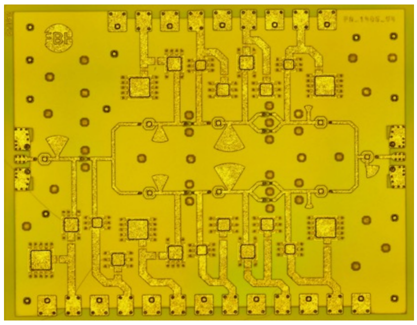
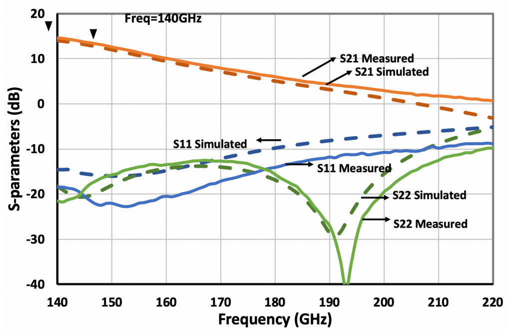


Fig. 7 The chip photograph of the D-band medium power amplifier (MPA).



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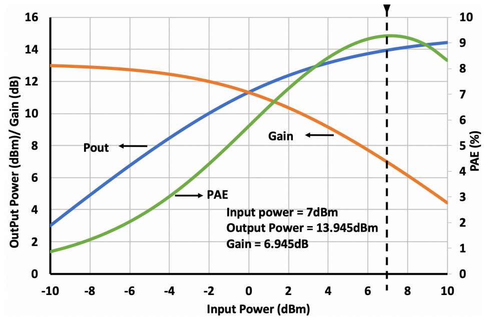

b)

Fig. 8 Measured (solid) and simulated (dash) a) s-parameters as well as b) simulated large signal performances of the D-Band medium power amplifier (MPA).

Fig. 8 presents the measured and simulated small signal as well as simulated large signal performances of the D-Band medium power amplifier (MPA). One can clearly see that the measured and the simulated small signal results agree well each other. The large signal measurement is ongoing, nevertheless the simulated large signal behavior predicts a P1dB compression point at an input power of 2 dBm and at an output power of 12 dBm. The simulated saturated output power is 14 dBm at a maximum power-added efficiency (PAE) of 9% to be expected.

F. Image Rejection filter

The image-rejection filter is realised in waveguide technology (Fig.9a). Its high-pass characteristic is shown in Fig. 9b. The cut-off frequency is 48 GHz. The insertion loss at frequencies above 49 GHz is less than 1 dB. The rejection at 43 GHz and below is better than 50 dB. The LO signal at 46-47 GHz has about 10 dB rejection. The rejection filter was fabricated by CNC milling with an insertion loss IL < 1.9 dB at D-band.

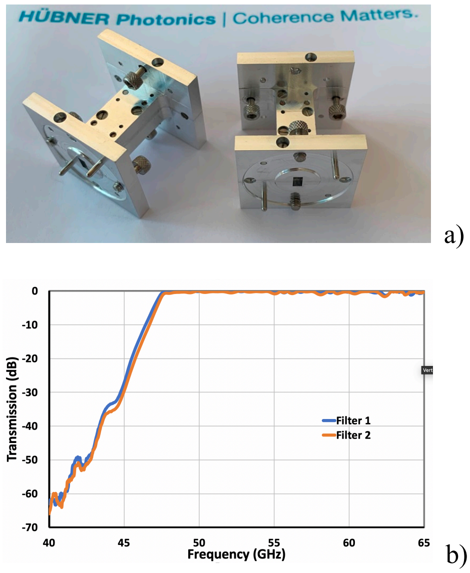

Fig. 9 Image Rejection filter, a) prototype, b) Transmission

G. D-band Horn Antenna

The transmission hub needs an antenna with a wide angular aperture to illuminate an area sector. A pyramidal horn low gain antenna was designed by the electromagnetic simulator CST, fabricated (Fig. 10a) and then measured in an anechoic chamber.

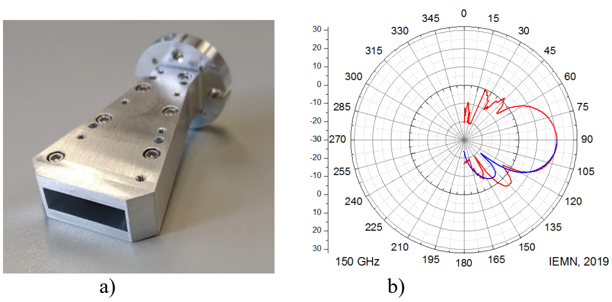

Fig. 10 a) D-band horn antenna and b) radiation diagram

The antenna was designed to have a gain of about 20 dB and main lobe width of 30° in the frequency range 140-150 GHz. The comparison of the measured and simulated radiation pattern at 150 GHz is reported in Fig. 10b.

II. Conclusion

The D-band transmission hub is in advanced fabrication stage. The novel components at D-band for the system have been described. Most of the components are at the state of the art. The full system will be assembled and tested in real environment.

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