Low-Cost Surface Mount Millimeter-Wave Transceiver Modules for LMDS Applications

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***Abstract* - Low-cost surface mount transceiver modules have been developed for 28 GHz and 38 GHz point-to-point LMDS applications in compliance with ETSI specifications. The transceivers consist of transmit (TX), receive (RX) and local oscillator (LO) functions integrated on a single millimeter-wave printed circuit board. The 38 GHz transceiver integrates new types of organic SMD packages developed in the 5th framework European IST project SMACKS and suitable for high power amplifiers. The module technology is fully compatible with standard high volume surface mount assembly, resulting in a significant cost reduction in terms of design, drawing, assembly, tuning and testing.**

I. INTRODUCTION

Millimeter-wave communication technologies offer great benefits for the deployment of radio networks such as Broadband Wireless Access and Point-to-Multipoint systems. In particular millimeter-wave equipments can provide high speed data rate and flexibility thanks to short wavelengths, high bandwidths and compact sized systems. Main applications are in VSAT, Point-to-Point (PTP) and Point-to-Multipoint (PTMP) communication. However today, millimeter-wave technology still lacks in providing competitive solutions for such systems. Current millimeter-wave transceiver designs rely on traditional hybrid assembly, where bare MMICs are mounted directly on a metal base plate and interconnected together with different types of organic and ceramic substrates using wire bonding. The assembly process and MMIC spreads introduce large dispersions which must be compensated by design and large electrical margins are required. The mass production of millimeter-wave transceivers in quantities required by the communication market is still a difficult challenge.

II. MILLIMETER-WAVE SMT TECHNOLOGY

Currently more and more commercial millimeter-wave MMICs available in surface mount (SMD) ceramic packages operating up to 40 GHz can be found on the market [1]-[3] but usually have limited performance particularly for high power applications, therefore limiting the overall system performance. In the 5th framework European IST "Surface Mount Assembly for Communication K-band Systems" (SMACKS) project, different types of low-cost SMD packages have been developed. Critical design rules have been followed in order to achieve high performance packaging suitable for LMDS applications. Such design rules include the minimization of ground inductance, the limitation to 20-25 dB gain amplifiers and the minimization package insertion loss at 0.5 dB per transition.

Within the SMACKS project, two types of SMD packages have been developed: LTTC packages for low power functions, and organic packages for high power and high gain functions. The LTCC package consists of two DuPont 951 ceramic layers and is 400 µm thick. The MMICs are directly mounted on top of the package on a array of vias providing RF and DC ground (Fig. 1 bottom). The organic package consists of one Rogers Ro4003 organic layer and is 200 µm thick. The MMICs are mounted on top of a copper carrier directly plated inside the package cavity (Fig. 1 top). The organic design has interesting benefits for millimeter-wave applications compared to LTCC: the reduced ground inductance provides extended frequency range up to 50 GHz and also improves the package thermal dissipation. While standard off-the-shelf ceramic packages are used in the 28 GHz transceiver, the SMACKS packages will be used in the 38 GHz transceiver.

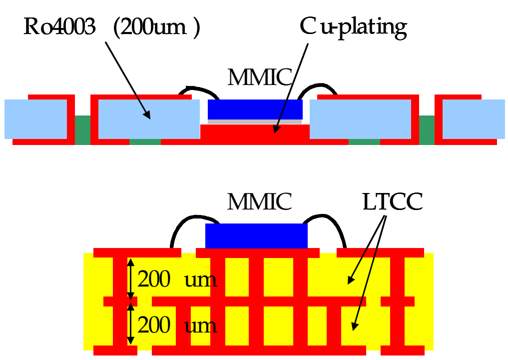

Fig. 1. Cross-section of SMACKS organic (top) and LTCC (bottom) millimeter-wave SMD packages.

III. 28 GHz Transceiver Module

A. Module Design

The 28 GHz transceiver module has been designed to operate in the 27-30 GHz band for low capacity point-to-multipoint LMDS applications. The target transmit output power is 22 dBm and the receive noise figure is 5 dB. In order to achieve the desired performance at a lower cost, standard off-the-shelf SMD components have been selected, for both transmit and receive channels. The overall chain performances have been predicted by gain block calculations which also include the determination of electrical margins with the specifications. A significant electrical margin is essential to ensure operation at all temperatures (-30°C to +80°C) and achieve high yield mass production. The order of the components has been optimised to achieve all transmit and receive requirements: TX and RX gain, dynamic range, TX output power, TX output IP3, TX and RX Noise Figure. During the design phase, requirements for standard high volume surface mount assembly process have been taken into account. The transceiver architecture is based on subharmonic up- and down-conversion and is shown in Fig. 2. The transmit chain consists of 5 packaged MMICs: 1 mixer, 2 drivers for gain, 1 power amplifier. Also an attenuator is inserted to control the gain and to compensate for both temperature and component dispersion. The receive chain consists of only 2 packaged MMICs: LNA and mixer.

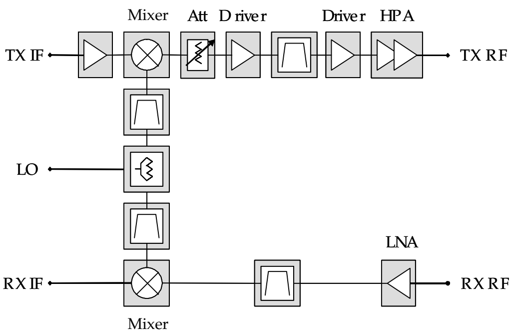

Fig. 2. Architecture of the 28 GHz transceiver.

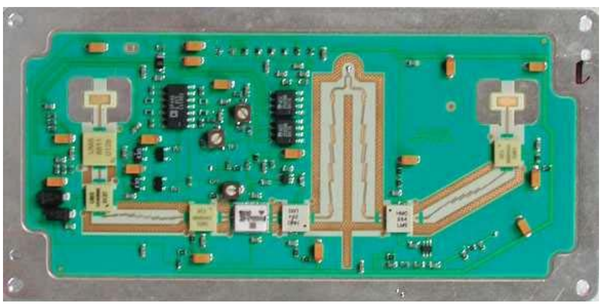

Fig. 3. Picture of the 28 GHz SMD transceiver.

B. Module Fabrication

The 28 GHz transceiver module has been fabricated and all the components have been mounted on a single motherboard, which is a 200 um thick Rogers Ro4003 substrate, using a standard reflow surface mount assembly process. The motherboard is bonded on a metal base plate using film glue. SMA connectors are then mounted for LO and IF signals. Optimised microstrip-to-waveguide transitions are used for the RF signals. Band pass filters for TX, RX and LO signals have also been integrated on the motherboard (Fig. 3) in order to provide spurious signals rejection.

C. Experimental Results

The transceiver has been fully characterized with transmit and receive IF center frequencies fixed at 4 GHz and 3 GHz, respectively. The LO signal is common to both channels and can be tuned within the 12-13 GHz frequency range. The LO input power is fixed at 3 dBm.

The measured TX output power is 22 dBm with 32 dB linear gain (Fig. 4). The gain dynamic range is 25 dB. The RX measured gain is 11 dB ± 1 dB, and measured noise figure 4.9 dB. The total DC consumption is 5V/800mA.

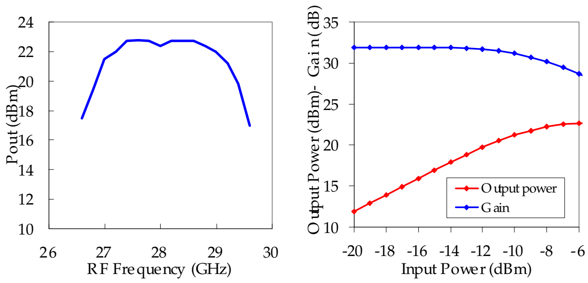

Fig. 4. Measured output power (left) and gain versus input power at LO=12.6 GHz (right).

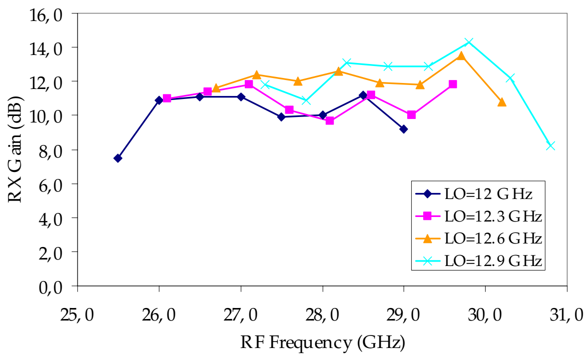

Fig. 5. Measured RX gain for various LO frequencies.

IV. 38 GHz Transceiver Module

A. Module Design

The 38 GHz transceiver module has been designed to operate in the 37-40 GHz band for high capacity point-to-point LMDS applications. The target transmit output power is 30 dBm and receive noise figure is 6 dB at 37-40 GHz. The design procedure is very similar to the 28 GHz case, and overall chain performances have been predicted by gain block calculations. The transceiver architecture is based on subharmonic up- and down-conversion and is shown in Fig. 6. The LO signal is 9-10 GHz and therefore a frequency doubler is necessary. In this case, each channel has a separate LO signal.

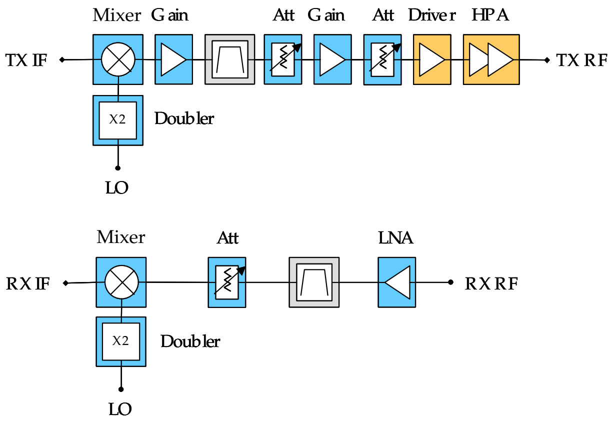

Fig. 6. Architecture of the 38 GHz transmitter (top) and receiver (bottom).

The transmit chain consists of 8 packaged MMICs: 1 frequency doubler on the LO path, 1 mixer, 2 gain blocks, 1 driver, 1 power amplifier, and two variable attenuators for gain control and temperature compensation. The HPA is a custom 1W, 15 dB gain amplifier designed within the SMACKS project, based on the commercial PPH15X power process from UMS. The receive chain consists of 4 packaged MMICs: 1 LNA, 1 variable attenuator for temperature compensation, 1 LO frequency doubler and 1 mixer. Except for the HPA, all other chips are commercially available MMICs. SMACKS organic packages described in Chapter II of the present paper have been designed and used for the driver and HPA. All other low-power functions have been encapsulated in SMACKS LTCC packages. The main expected performances are listed in Table I. The TX IM3 requirement is very stringent and implies the use of the SMACKS 1W power amplifier.

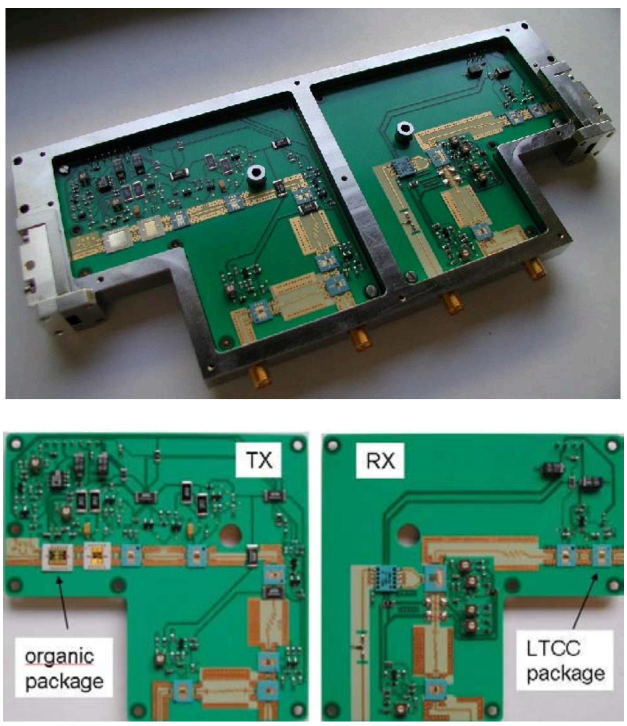

Fig. 7. Pictures of the SMACKS 38 GHz transceiver (top) and millimeter-wave motherboards (bottom).

B. Module fabrication

The fabricated 38 GHz transceiver is shown in Fig. 7 and is currently under characterisation.

Channel	Parameter	Specification
TX	RF frequency range	37-39.5 GHz
	IF frequency	2.34 GHz
	Output power range	-5 to +21 dBm
	Dynamic range	> 50 dB
	IM3 @ 17.5 dBm	< -38 dBc
RX	RF frequency range	37-39.5 GHz
	IF frequency	1.08 GHz
	NF min.	< 6 dB
	Gain	12 ± 2 dB
	Dynamic range	> 25 dB
Temperature range		-35°C to +80°C

Table I. Target specifications for the 38 GHz module.

V. Conclusion

Millimeter-wave transceivers using standard SMT technology have been presented. Measured and expected performances are 22 dBm at 28 GHz and 30 dBm at 38 GHz. New organic SMT packages have been introduced for high power functions. This demonstrates the availability of SMT assembly process for millimeter-wave communication systems, allowing the mass production of MMW transceivers and resulting in a significant cost reduction estimated at 20%.

Acknowledgements

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