Point-to-Multipoint Transceiver in LTCC for 26 GHz

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Abstract

A point-to-multipoint transceiver module for 24.5 GHz to 26.5 GHz has been developed. Such a module is applied in public or private cellular networks known as LMDS (Local Multipoint Distribution Services). The recommendation "T/R 13-02" from CEPT[1]/ERO[2] has been utilized to design the circuits for its operation in terminal and base stations (see figure 1). The result is a very compact microwave multichip module with a 5 layer LTCC substrate, 12 GaAs MMICs mounted in stepped cavities, several SMD and hybrid components on the top, buried bandpass filters and optimised waveguide transitions. The T/R module is composed of a transmit (Tx), receive (Rx) and LO (local oscillator) path. These parts are shielded by using via fences through the substrate layers and metal walls in the cap. The module size is 61 mm x 37 mm including the aluminium housing. This development is a result of the European research project RAMP[3], which was running from 1998 until 2001. The design, assembly, characterization and evaluation has been performed by the authors, while Thales Microelectronics in France has manufactured the LTCC substrate and NMRC in Ireland the thermal management.

Key words: LTCC Multilayer Ceramic, Microwave Application, Package Design, Thermal Management

Design and Manufacturing

The goal of this development is the demonstration, that LTCC multilayer technology has great benefits in microwave applications: high level of integration, buried components, low losses, robustness, cavities for mounting MMICs, TCE close to GaAs, good thermal conductivity due to thermal management and others. On the other hand digital radio networks, like point-to-point and point-to-multipoint applications are considered to become a growing market even if optical links are in strong competition. This requires low cost components. Especially the RF parts are driven by the high costs of integrated circuits and the commonly used thinfilm technology. Thus the consortium decided to develop a transceiver module for LMDS in a frequency band of 24.5GHz to 26.5GHz on the low cost LTCC technology with screen printed conductors. In early tests Ferro's A6M tape has shown the required microwave behaviour. The design starts with the synthesis of microstrip (MS) and stripline (SL) waveguides, followed by the optimisation of transitions and feedthroughs from one waveguide to an other. It could be demonstrated, that these RF structures fulfil the required specifications [1-3]. In the next step MMIC circuits have been mounted on top and into simple and stepped cavities of multilayer LTCC substrates. Again the results were very successful [4]. Even aperture coupled patch-antennas on LTCC with feeding networks on the backside have been designed and tested for 24 GHz ISM-band applications [5]. All these preceding tests have been performed as a preparation for the LMDS module development. Figure 2 shows a photo of the final circuit.

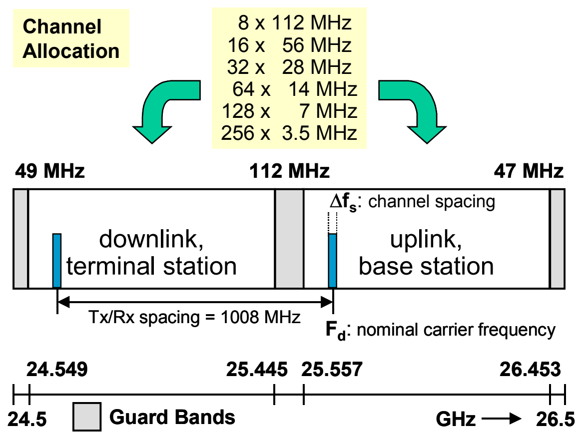

Figure 1. CEPT[1]/ERO[2] recommendation T/R 13-02 for digital radio relay systems

[1] European Conference of Postal and Telecommunications Administrations
[2] European Radio Communication Office
[3] Rapid Manufacture of Microwave and Power Modules, BriteEuram III (BE-97-4883)

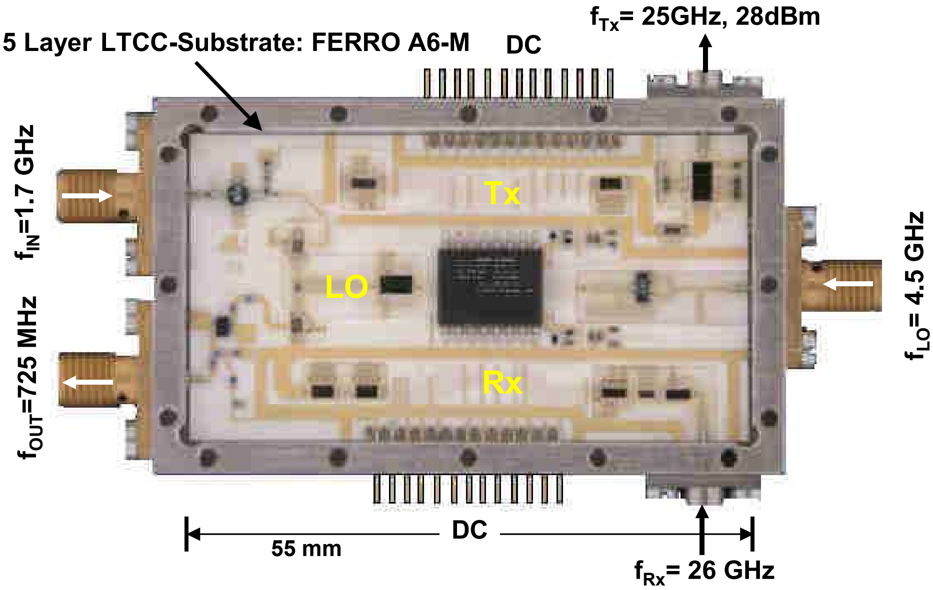

Figure 2. Photo of the LMDS transceiver module (for terminal station)

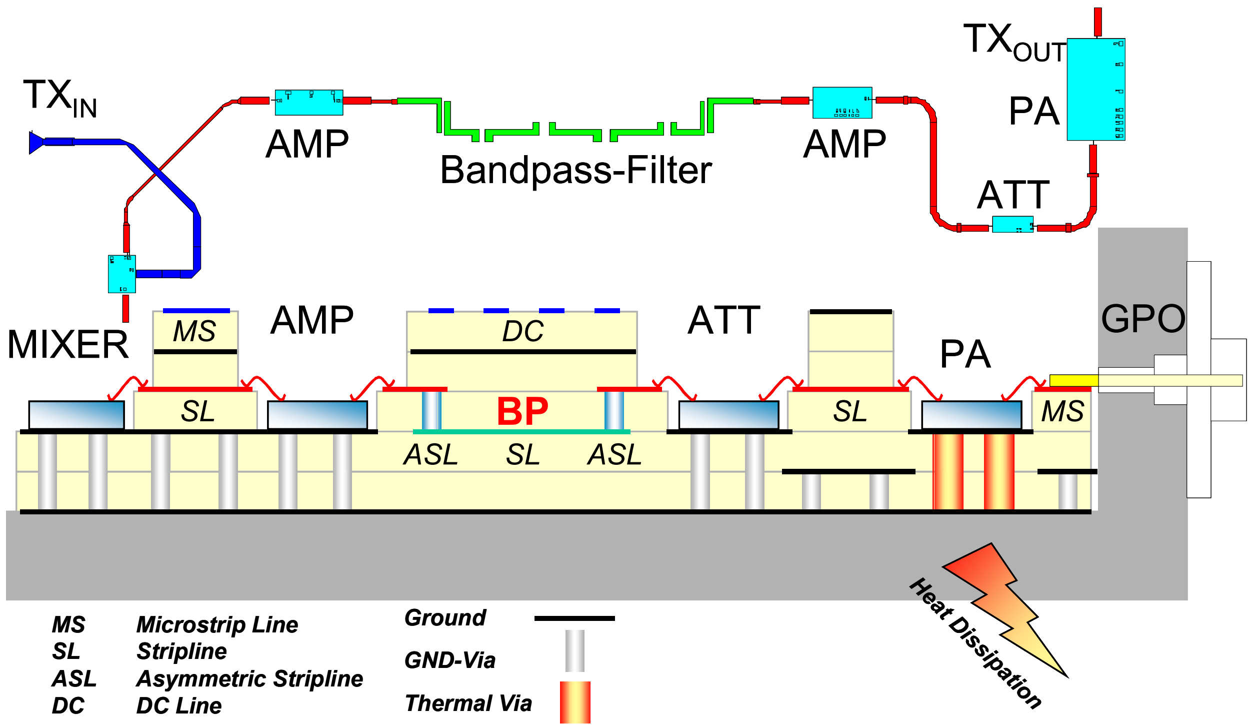

Figure 3. Schematic top and cross view of the transmit path of the LMDS module

The complexity of the circuit becomes evident, when the schematic top and cross view of the transmit path is considered in figure 3. The explanation starts with the transmit input port (TX_{IN}) which is connected to a microstrip line on top of the LTCC (in blue). The TX-signal is guided to a mixer in a stepped cavity. A wire bond connects the mixer with a MS line in the cavity. A feedthrough with a short stripline (in red) follows. This allows the crossing of a MS line. The output port of the amplifier (AMP), which is also mounted in a stepped cavity, is connected with a MS-ASL-SL transition, where ASL means asymmetric stripline, because only one substrate layer is above and three layers are below the conductor strip. A bandpass filter has been designed in the SL level (in green) [6]. L-shaped coupled segments are used. The filter is shielded by via fences on the left and right sight of these segments. The vias are connected with the top and bottom ground plane. DC lines are crossing the filter on top of the substrate. Attenuator (ATT) and power amplifier (PA) are integrated in the same way like the other MMICs. Special micro-connectors (GPO from Gilbert) are utilized for the microwave ports. It is important to mention, that each inner ground layer is directly connected with the aluminium housing using dense arrays auf filled via.

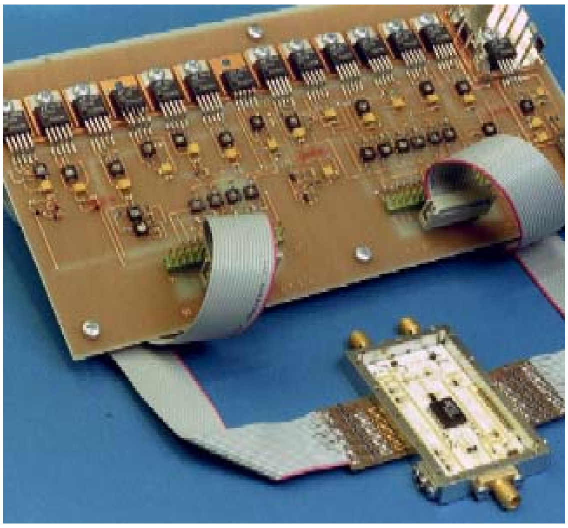

Figure 4. DC power supply board connected with LMDS frontend

Thales Microelectronics in France has manufactured the LTCC substrate. Ferro's A6M tape with mixed metal conductors has been utilized. The 6-inch wafer carries further test circuits and conductors lines for calibration purpose. IMST has diced the wafer, mounted the substrate into the package and assembled the MMICs and SMD components. A DC power supply board has been developed to adjust each individual DC voltage to the MMIC chips. Figure 4 shows a photo of the board connected to the transceiver module.

Heat Management

A special heat management for the PA has been introduced: An array of 21 silver filled via holes was placed under the amplifier chip to increase the thermal conductivity of the LTCC substrate. The thermal resistance of the Ferro A6 tape is 2W/mK, which is better in comparison with PTFE boards (around 0.15 to 0.35W/mK) but worse compared to Alumina substrates (16 to 20W/mK). The thermal resistance of silver vias is around 150W/mk, which results in a common thermal resistance of about 20 to 30W/mK depending on the density of the vias in the array. Marconi's (today Bookham) PA has a RF output power of 28dBm causing a thermal energy of 2.4W, which has to be dissipated from the transistors through the substrate and the aluminium housing. Ireland's ICT Research Centre NMRC has simulated and optimised the heat dissipation for the LMDS application. The result of the junction to case simulation is illustrated in figure 5: The PA, which has a power added efficiency (PAE) of 20% consists of 3 amplifier stages and 7 transistors (pHEMT) in total. The most heat is generated from the 3rd (output-) stage, which is roughly 1.4W. The dark-red area indicates the heat concentration below the 4 transistors. The simulation takes the thermal conductivity (R_{th} [W/mK]) of each material into account: GaAs: 54, die attach: 3, LTCC: 2, thermal via: 150 and aluminium: 200. With a case temperature of 80°C a maximum temperature of T_{max} = 110°C can be achieved, while the maximum junction temperature of the PA module is 150°C.

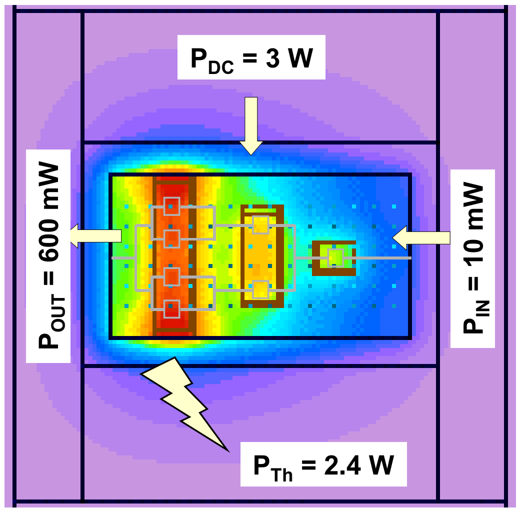

Figure 5. Thermal simulation of PA with via array for heat dissipation

Characterization and Evaluation

The evaluation started with the test circuits, which are identical to the components of the LMDS module. Especially the bandpass filters have critical specifications, because they cover the transmit and receive bands, which are very close together. Figure 6 shows the filter response of the 25GHz filter split into specifications, simulated and measured return and insertion losses. The data agree very well and fit into the specifications. A photo of the test circuit is placed on the bottom of the diagram. The top ground plane, the vias (small dots) and the cavities with the RF ports inside are visible. The optimisation of the filter has been performed with the 3D full-wave simulation tool EMPIRE™, which is a software tool of IMST. Figure 7 gives a visualization of the current distribution on the inner filter segments. Top and button ground as well as the substrate layers are faded out to allow a view into the stripline area. The shielding via fence is still visible. The field shot has been taken in the passband at 25GHz. The red peaks especially at the conductor edges indicate a high current level.

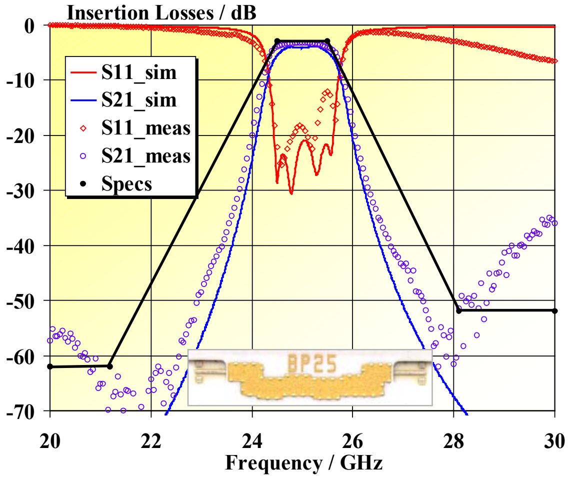

Figure 6. Specification, simulation and measurement of the 25GHz bandpass filter

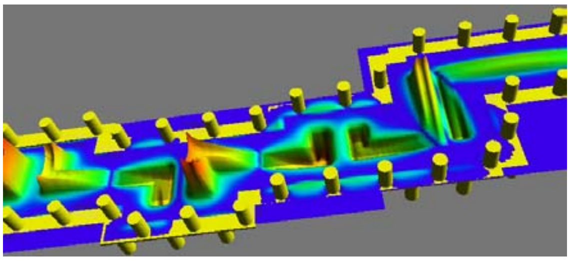

Figure 7. Current distribution in pass-band of BP-filter at 25GHz

This is only one example for the evaluation of the test circuits. In the next step each single component has been tested inside the LMDS module. The DC power supply circuit was connected to the RF module to find out the optimum biasing points for each MMIC. The RF ports remained unconnected for the first test. A photo with the DC board and RF module is presented in figure 4. Next, all unconnected RF wire bonds have been assembled to characterize the overall performance of the transceiver. Not all expected specification which are listed in table 1 could be fulfilled. However, the authors have demonstrated that the multilayer LTCC technology is capable to be used in complex microwave applications. With the experience gained from design and manufacturing of this demonstration module, it would be possible to fulfil the specification with a re-design.

	Terminal Station	Base Station
f_{LO} [GHz]	23.88 – 24.664	26.338 – 27.112
f_{VCO} [GHz]	3.980 – 4.111	4.390 – 4.520
f_{Txout} [GHz]	25.557 – 26.453	24.549 – 25.445
f_{Txin} [GHz]	1.733	1.733
f_{Rxin} [GHz]	24.549 – 25.445	25.557 – 26.453
f_{Rxout} [MHz]	725	725

Power and Gain		Other Parameters	
P_{VCO}	10 dBm	Harmonics	< -30 dBc
P_{TX}	4 – 28 dBm	Spurious	< -50 dBc
G_{TX}	56 dB	Phase Noise	./.
P_{RX}	-18 – 16 dBm		
G_{RX}	65 dB		

Table 1. Specifications for T/R-Module

Acknowledgement

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