Low Cost Ka Band Transmitter Modules for LMDS Equipment Mass Production

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Abstract: *Two different Ka band medium power transmitters for LMDS (Local Multipoint Distribution System) applications have been designed proving successful performance while introducing low cost components and simple mounting techniques for industrial purposes. Commercially available BGA and LM packaged components are attached with epoxy dispensing procedures to a* 0.254 *mm height cost effective plastic substrate. The output power stages are die form MMIC amplifiers which are first mounted on separate carriers. A novel epoxy-on-bonding die attaching technique is used in order to prevent undesired bonding to plastic quality and performance. New active biasing networks are employed so that no later adjustment is necessary to control the overall transmitter behaviour. Active biasing also allows higher PAE than usual resistor dividers for gate biasing while preserving linearity and P1dB output power. The transmitter modules work at* 31.15 *GHz and* 25.7 *GHz respectively. The measured P1dB was* 26.5 *dBm and PAE at P1dB was 16 %.*

Introduction

Broadband wireless access to multimedia applications is becoming a growing and emerging market which demands as the basic need for its development commercially available efficient and cost effective products and equipment. Special efforts are being made to implement Ka band devices for this kind of applications achiving high output power levels and high efficiency [1], [2] and [3], high linearity behaviour [4], large working power densities [5], small size [6], and low cost, making use of novel power combining structures [7], new die fabrication materials and processes, and novel amplifier structures and configurations [8]. Also strong efforts are being made in the field of packaging technology for Ka band microwave devices. Recent results have shown low losses and very good performance at 30.0 *GHz* and above [3], [9] and [10]. Despite this large amount of work involving LMDS technology, the situation is far from translating to the production of readily available products for industrial series production which is in fact what this market needs in order to keep growing. Small efforts are being made to accommodate these investigations to the design of practical modules [11], [12]. Some of the key clues for designing ready to use products for LMDS applications have been recently pointed out [13].

This paper describes the techniques used in the design of two Ka band transmitter modules for LMDS applications. Low cost, high performance and simple mounting techniques are achived trough the use of plastic substrate, commercially available BGA and LM packaged components, and novel considerations on biasing networks for the amplifier stages and on bonding-on-plastic attachment for the die form power stage components. These last two key ideas given in order to obtain high performance and no later system adjustment, and high bonding quality and reliability for hadling and mounting purposes respectively.

Although previous works have reported convincing performance of their designed modules no packaged Ka components have ever been used in commercial systems [11] and [7]. Die form components are cheaper than packaged ones but assembling process is much simpler if surface mounting devices are instead employed. Also other works have reported extremely high performance at the expense of cost and system mounting simplicity [6].

Our transmitter module meets high performance, low cost and simple mounting and assembling through the use of the components and techniques which will be next described in the following sections.

System description

Both designed transmitter modules share the same structure shown in fig. 1.

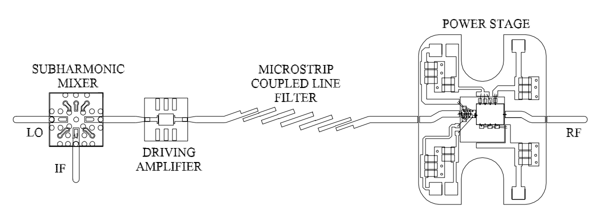

Figure 1: Designed modules configuration.

A commercial subharmonically pumped BGA packaged [10] mixer is used to obtain the RF signal $f_{RF} = 2f_{OL} + f_{FI}$, where f_{RF} is 31.15 GHz or 25.7 GHz. The radiofrequency signal is then amplified through the use of an LM packaged predriving amplifier and then filtered in order to eliminate the undesired signal $2f_{OL}$. The response of the filters used in each system are shown in fig. 2. Montecarlo analysis were carried out on the designed filter physical dimensions in order to guarantee the desired filter response performance. The allowed drifts were as large as $\pm 25\ \mu m$.

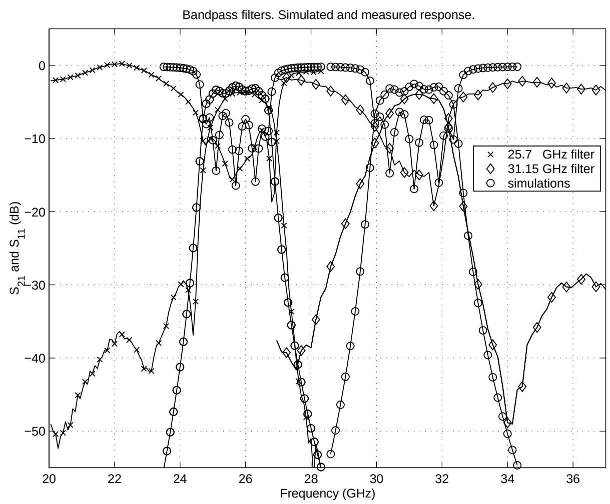

Figure 2: Simulated and measured response of 25.7 GHz and 31.15 GHz filters.

In order to obtain the desired output power the signal must be once more preamplified before it reaches the final high power amplifier. Both amplifiers are shown in fig. 3 for the system working at 25.7 GHz.

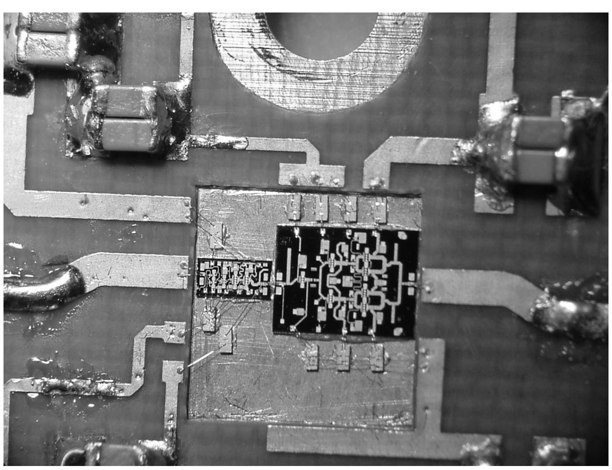

Figure 3: Power stage for the 25.7 GHz transmitter module prototype.

The elements which form the complete transmitter schemes were chosen so that the overall $P1dB$ point was given by the high power amplifier, thus ensuring the required linearity performance for LMDS applications for QPSK modulation as well as for high spectrally efficient modulations like QAM. Table 1 resumes the key characteristics of the previously mentioned modules' subsystems.

Table 1: P1dB and small signal gain figures for both systems 31.15 GHz and 25.7 GHz.

TRANSMITTER MODULE	31.15 GHz		25.7 GHz	
	$P1dB_0$ (dBm)	G (dB)	$P1dB_0$ (dBm)	G (dB)
MIXER	-11.0	-13.0	-11.0	-13.0
PREDRIVER	12.0	12.0	12.0	12.0
FILTER		-3.5		-3.5
DRIVER	21.0	19.0	22.0	20.0
HP AMP	27.0	9.0	28.0	20.0

Mounting techniques and design considerations

The transmitter modules were assembled on a 0.254 mm thick low cost plastic substrate. The substrate characteristics are: $\epsilon_r = 2.17$, $T = 0.005\ mm$, $Rho = 0.71$, $Rgh = 0.002$, $tan\delta = 0.003$, and measured losses of 0.12 dB/cm at 10.0 GHz and 0.37 dB/cm at 30.0 GHz.

Packaged components like the preamplifier shown in fig. 4 were employed. MMIC's packaged this way are easy to mount and handle, simple to test and cheap to use. Additionally no monolithic capacitors are necessary to prevent oscillations from taking place. Special care though must be observed when package attachment to the substrate is performed. Undesired oscillations appeared when a correct ground plane under the packaged component was not suitably guaranteed as shown in fig. 5.

Later system adjustments may be minimized if active biasing networks for device biasing are used (see fig. 6). Once I_D is fixed, the network automatically sets gate voltage V_G for drain voltage V_D. PAE at P1dB improvements when employing this kind of networks will be demonstrated in next section.

Also bonding on plastic flexible substrate quality and performance [14] increase if deposition of conductive epoxy drops on the bonding contact to the substrate is considered (see fig. 7).

Measurements and results

P_{in} vs P_{out} measurements were performed on the final output power stage for both modules. The results for the 31.15 GHz module are shown in fig. 8

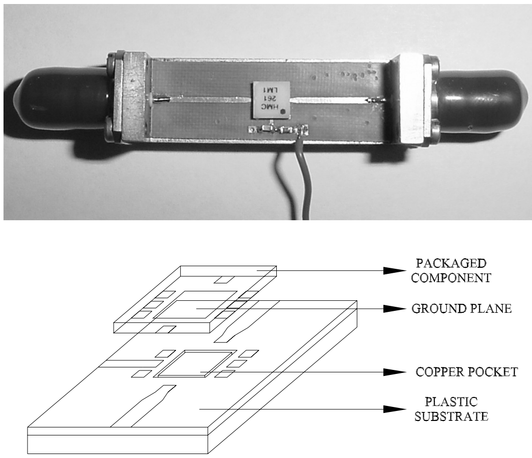

Figure 4: a. Predriver amplifier and measurement fixture. b. Correct ground plane mounting structure.

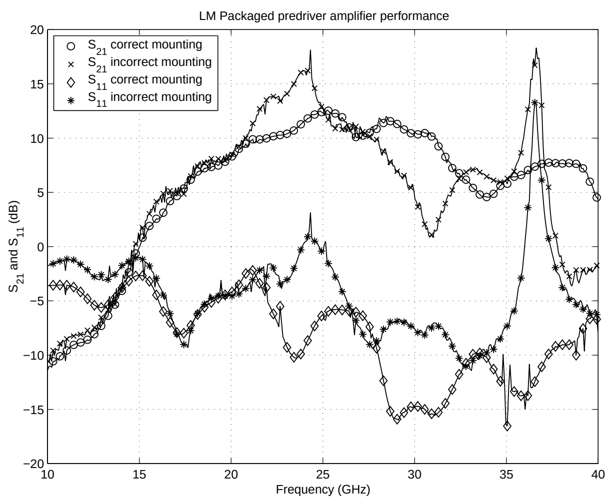

Figure 5: Small signal parameters measurement for correct and incorrect mounting structure.

demonstrating higher PAE figures when employing active biasing servos.

Also two tone measurements were made to prove the linearity response of the whole transmitter chain. The measured results are given in fig. 9 showing similar performance with both active and resitor divider biasing.

Table 2 resumes the 31.15 GHz transmitter module main features.

Table 2: 31.15 GHz transmitter module measured figures.

f_0 (GHz)	31.15
$P1dB$ (dBm)	26.3
P_{dc} (W)	2.9
PAE (%)	15.3

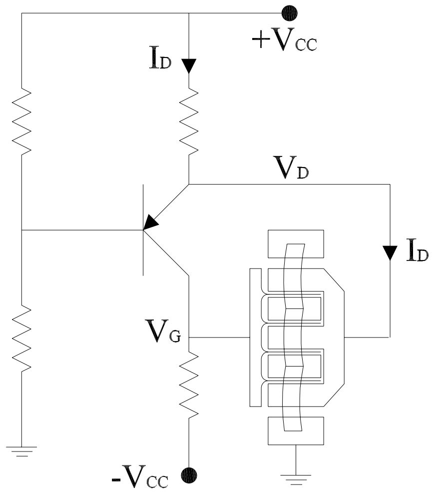

Figure 6: Active biasing network for PAE improvement and avoiding adjustments.

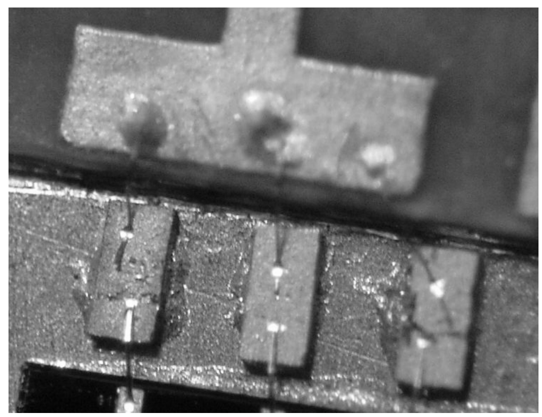

Figure 7: Epoxy on bonding deposition.

Conclusions

Two low cost medium power Ka band transmitter modules for LMDS applications have been designed (see fig. 11) and measured. An epoxy-on-bonding technique to increase reliability for die attachment on plastic has been employed. BGA and LM packaged components were also used. Active biasing servos allowed higher PAE than traditional resistor dividers for gate biasing while preserving P1dB and linearity properties.

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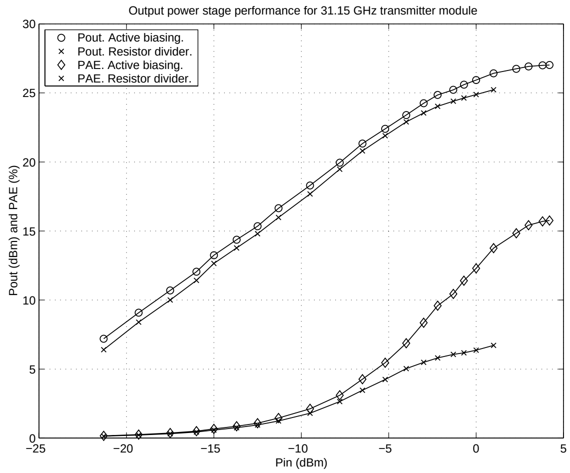

Figure 8: Power stage performance for 31.15 GHz module. Both measurements for the same DC power conssumption without RF signal (900 mA @ 3.5 V).

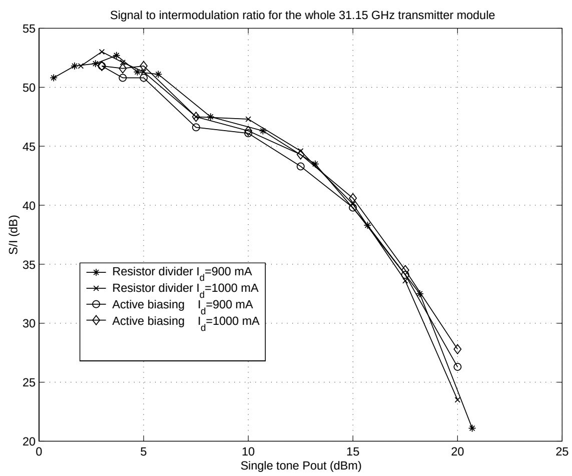

Figure 9: Signal to intermodulation ratio for the whole 31.15 GHz transmitter module.

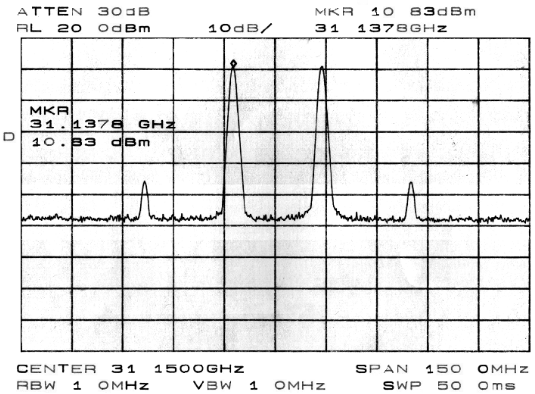

Figure 10: Two tone measurement example for the whole 31.15 GHz transmitter module. Single tone P_{out} was 12.0 dBm

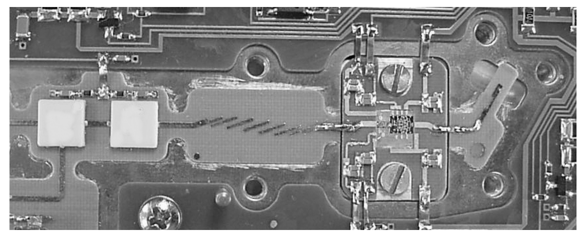

Figure 11: 25.7 GHz transmitter full production module.

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