

Millimeter-wave Radio System In A Package

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Abstract

The thirst for higher data rates and more bandwidth has resulted in increased interest in millimeter-wave systems as a means for local and wider area information transport. At the same time there is a real need for lower cost and more compact systems. These requirements have lead to the development of a highly integrated millimeter-wave System In a Package (SIP) which operates beyond 40GHz. This solution uses low cost ceramic packaging and optimized interconnects and transitions to allow for wide band electrical performance. This paper will present details on the functionality, electrical performance and packaging used to realize this solution.

Key Words: Microwave, Millimeter-wave, Transceiver, Receiver.

Introduction

Millimeter-wave point to point and other communication systems require the use of a down converter. The down converter translates the desired signal down to a frequency that can be used by the analog to digital converter.

The requirements for these systems have lead to the development of a highly integrated millimeter-wave System In a Package (SIP). It operates beyond 40GHz.

The solution uses low cost ceramic packaging and optimized interconnects and transitions to allow for wide band electrical performance. This paper will present details on the functionality, electrical performance and packaging used to realize this solution.

Material Parameter	Value
Dielectric Constant (10 GHz)	9.2
Dielectric Constant (30 GHz)	9.2
Loss Tangent (10 GHz)	0.003
Loss Tangent (30 GHz)	0.004
Dielectric Strength	11.6 KV/mm, 295 V/mil

Table 1. Electrical properties of HTCC.

1.0 Package Solution

HTCC and LTCC are possible solutions for IC and SIP at millimeter-wave frequencies. Table 1 shows the material properties of HTCC. Note that the loss tangent is reasonable to 30GHz.

The rf signal insertion loss due to dielectric loss is proportional to frequency and dielectric loss tangent.

Figure 1 shows a Hermetic HTCC package. Note that there are 50 ohm loads connected inside the package to the rf input

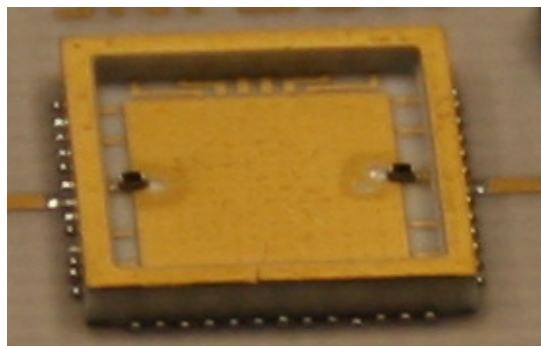


Figure 1. Hermetic QFN style package. Courtesy of Microwave Packaging Technology, Inc.

and output lines.

Figure 2 shows the test fixture used in measuring the Hermetic HTCC package. Note that the test fixture has 2.4mm input and output connectors for high quality signal transition to the motherboard. The motherboard is 0.008" Rogers RO4003 material. The thickness and material type were chosen for optimum bandwidth and low dispersion.

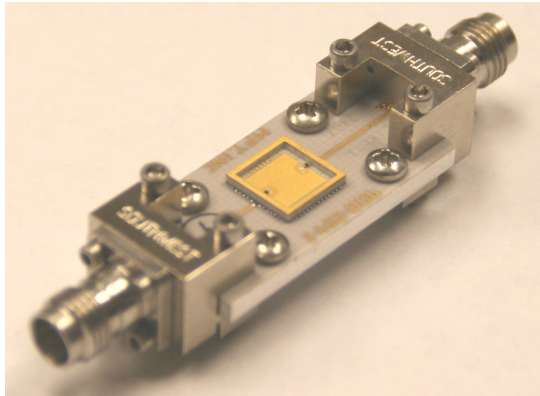


Figure 2. Test fixture used to measure the Hermetic HTCC package.

While recent work has shown the ability of HTCC and LTCC to achieve millimeter-wave performance for surface mount IC packages [1], there is a need for lower cost packaging solutions. Another issue is the rf signal's insertion loss through the package due to the dielectric loss and metal loss from refractor metals used in HTCC. Although HTCC can be used to 40GHz or higher for some systems, insertion loss limits the useable bandwidth of HTCC for many systems to 30GHz. For these reasons there is a need for very low cost ceramic based packaging that has good performance to 40GHz and beyond.

The solution presented here uses a low cost fabrication method based upon alumina ceramic. This technology eliminates the limitation of refractory metals and uses high conductivity gold metallization. The innovation is not in the processing, as rather standard processes are used. The innovation

is in the design of the rf sections of the package to yield much larger rf bandwidths than have been possible.

This solution has been applied to a millimeter-wave receiver package.

3.0 Receiver Description

The receiver design and component selection was based on achieving high performance in receiver IP3, P1dB and noise figure. Also, the elimination of spurs in the integrated VCO was an important consideration.

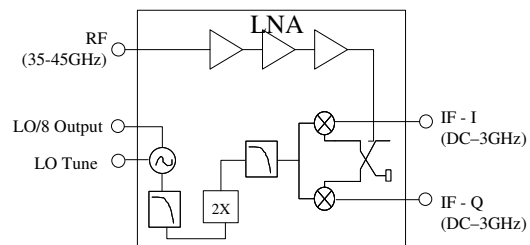


Figure 3 shows the block diagram of the millimeter-wave receiver. Note that the receiver has:

- VCO
- 1/8 LO frequency output
- Dual LO Filtering
- Frequency Doubler
- I/Q mixer
- Low Noise Amplifier

The VCO can be attached to an external phase locked loop using the divided output. This is important in most any practical application.

The I/Q output has a bandwidth from DC to 3GHz. The receiver predicted noise figure is 2.8dB at 38GHz. It also has a P1dB of 9.7dBm and an IP3 of 20.2dBm. The receiver was packaged into an 8x8mm package.

The filters were designed and fabricated using thin film processing. Figure 4 shows the design results for the lower frequency filter. Note that the filter is a low pass type and uses open stubs to approximate an

elliptic function response. The filter was designed using Microwave Office from Applied Wave Research. It was also subjected to electromagnetic analysis using EM Sight also from Applied Wave Research.

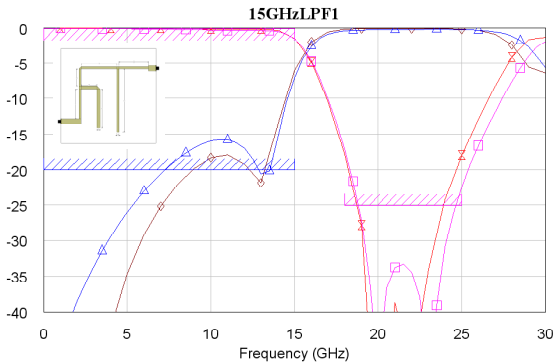


Figure 4. Electromagnetic simulation results for lower frequency filter.

The other low pass filter was also designed and analyzed using the same software tools. The results are shown in Figure 5. It uses a similar technique but also has three insertion loss poles and higher frequency.

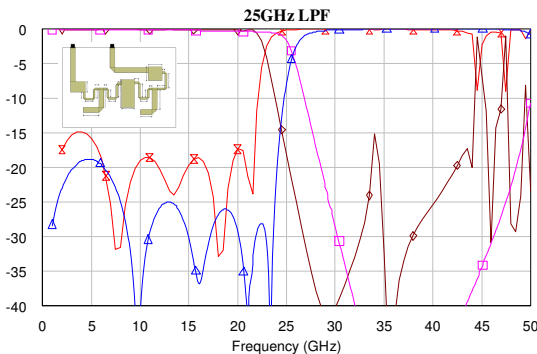


Figure 5. Electromagnetic simulation results for the higher frequency filter.

4.0 MMW Receiver Realization

The receiver was fabricated and measured. Figure 6 shows an image of the receiver. Note how the MMICs, Filters, bias circuitry and interconnections are all contained in the package.

The components were attached using conductive epoxy. In this case it was H20E because of its ease of use and two-part storage. The interconnects between the

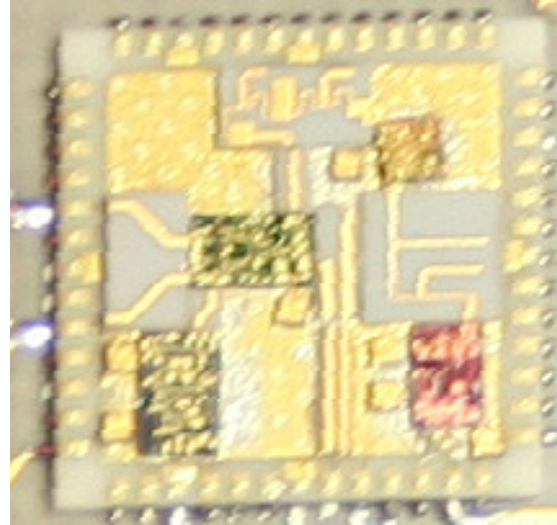


Figure 6. Image showing the mmw radio.

MMICs, filters and interconnecting lines is with 1 mil diameter gold wire.

The package is covered with a b-stage epoxy lid.

The measured results are summarized in Table 2.

Parameter	Performance	Units
Gain	14	dB
Noise Figure	2.9	dB
P1dB	10.1	dBm
1P3	22	dBm
IF BW	3	GHz
RF BW	35-45	GHz

Table 2. Summary of measured performance.

Conclusions

It is possible to realize a MMW radio system in a package using high quality transition and interconnect to get the signal from the motherboard into the package. This paper details a package which has a fully integrated millimeter-wave package.

References

- [1] R. Sturdivant, "Millimeter-wave Performance Of Alumina High Temperature Cofired Ceramics IC Packages," 2006 IMAPS Conference, San Diego, CA