

CAD BENCHMARK

This is the fourth and final part of the this year's CAD Benchmark, a millimetre-wave rat-race mixer problem that was first outlined in the October 2001 issue. In this part author of the original problem, Jason Lynch of Farran Technology, provides a comparison of the simulated and measured results for the actual hardware.

ZUSAMMENFASSUNG

Das 2001 CAD Benchmark

Dies ist der vierte und abschliessende Teil des diesjährigen CAD-Benchmarks, das Problem eines Mikrowellen-Mischers, das in der Ausgabe vom Oktober 2001 beschrieben war. In diesem Teil vergleicht der Autor des Problems, Jason Lynch von Farran Technology, die simulierten mit den an realisierter Hardware gemessenen Ergebnissen.

SOMMAIRE

Les essais comparatifs de CAO 2001

Voici la quatrième partie des résultats du Benchmark CAO de cette année, avec le problème du mélangeur 'rat-race' millimétrique qui avait été décrit dans le numéro du mois d'octobre. Dans cette partie, l'auteur du problème original, Jason Lynch de Farran Technology, fournit une comparaison des résultats simulés et de ceux mesurés pour le matériel réel.

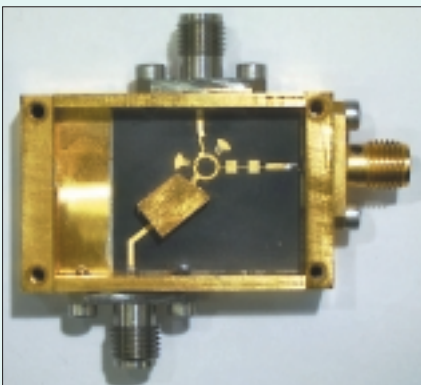


Figure 1: Mixer test structure from Farran Technology

FARRAN TECHNOLOGY

Comparison of participants' results with measured data

Measurement System

The following equipment was used in the measurement setup for the mixer

- Anritsu Wiltron 54177A 10MHz – 50GHz Scalar Analyser System
- Agilent 83640B 10MHz – 40GHz Swept Signal Generator
- Agilent E4418A Power Meter
- Agilent 8485A 50MHz – 26.5GHz Power Sensor
- Agilent R8486A 26.5 – 40GHz Power Sensor
- Agilent 8564EC 30Hz – 40GHz Spectrum Analyser
- Farran Technology Model FPA-28S Power Amplifier

Conversion Loss

Upconverter (Figures 2 & 3)

AC Microwave: The frequency response is good. But at low power levels of LO and especially RF a ripple is seen in the passband which does not occur in the measurements.

APLAC: The frequency and conversion loss is poor when compared with the test results, except when the LO is +15dBm. At this point the response is good.

AWR: The bandwidth is smaller than observed in test, but the value conversion loss in the band compares well with measurement.

Eagleware: Seems to give the best simulation results with the best frequency response and the conversion loss is also close to measurement.

Downconverter (Figures 4 & 5)

AC Microwave: The frequency response is good. But at low powers of LO and especially RF power levels a large ripple is seen in the passband which does not occur in the measurements. The conversion loss simulated is less than that seen in the tests.

APLAC: The frequency response is good, but again the lower LO powers do not give a good approximation to the actual conversion loss.

AWR: The frequency response of the passband is shifted by approximately 250MHz. However the simulated conversion loss value in the band compares very well to the measured results.

Eagleware: As before the frequency and conversion loss responses are very good.

Compression (Figures 6 & 7)

AC Microwave: Simulation results show P1dB to be at about +10dBm for both up and downconverters.

APLAC: Downconverter P1dB given as about +10dBm input power. The value from the upconverter compression graph is not clear.

AWR: Downconverter compression seems to be following test results but not taken far enough. Upconverter seems to be similar to

APLAC's results but again is not taken to a high enough input power.

Eagleware: P1dB point is high (+14dBm input power) compared with measured result (LO power not given).

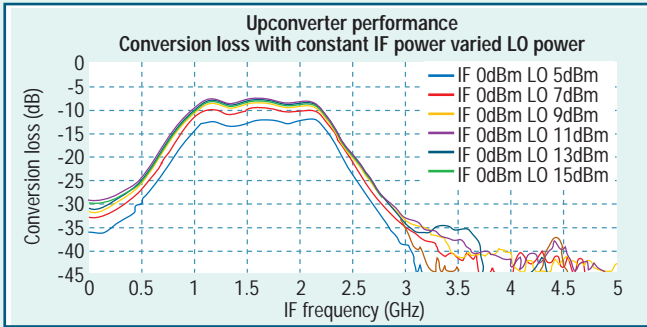


Figure 2: Upconverter conversion loss with constant IF power for various LO power levels

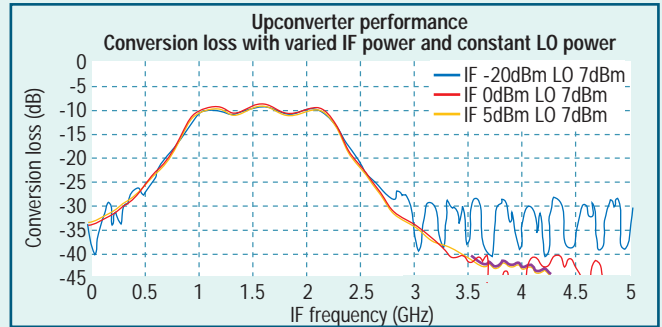


Figure 3: Upconverter conversion loss with constant LO power for various IF power levels

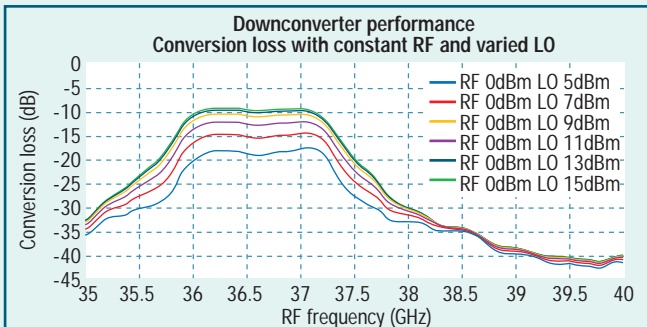


Figure 4: Downconverter conversion loss with constant RF power for various LO power levels

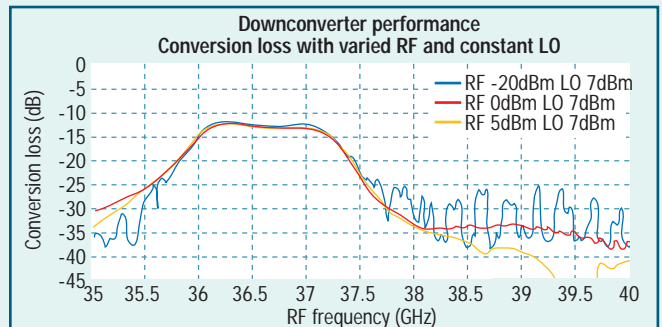


Figure 5: Downconverter conversion loss with constant LO power for various RF power levels

Isolation (Figures 8 & 9)

AC Microwave: LO isolation at RF port results very similar. IF isolation at RF port is not good (value <30dB out). LO isolation at IF port simulated better than actual measured value (20dB). RF isolation at IF port simulated

slightly worse than measured values (10dB).

APLAC: LO isolation at RF port results are worse than simulated (10dB). IF isolation at RF port very good as it suggests a very low level, which is what we found. LO isolation at IF port

simulated very close to the measured values. RF isolation at IF port: the measured results are a lot better than the simulated (20dB better).

AWR: LO isolation at RF port are not as good as simulated (10dB too low). LO isolation at IF port results are

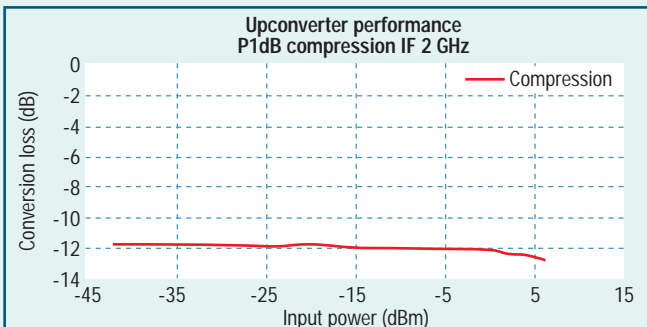


Figure 6: Upconverter 1dB power compression (IF = 2GHz), showing P1dB ~ +6dBm input power for a LO power of +12dBm

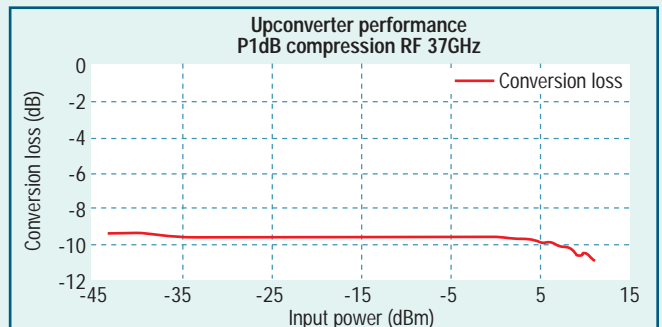


Figure 7: Downconverter 1dB power compression (RF = 37GHz), showing P1dB ~ +8.5dBm input power for a LO input power of +12dBm

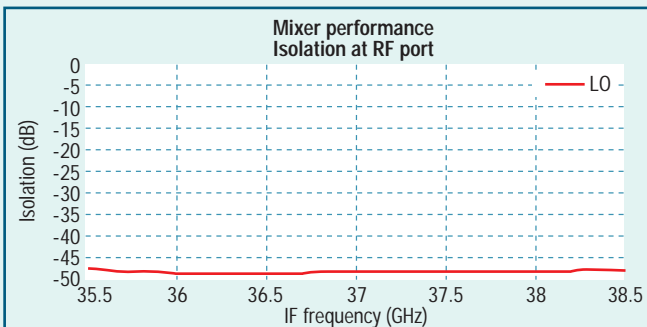


Figure 8: Mixer isolation at RF port. The IF level at the RF port was too low to be measured (<-60dBm)

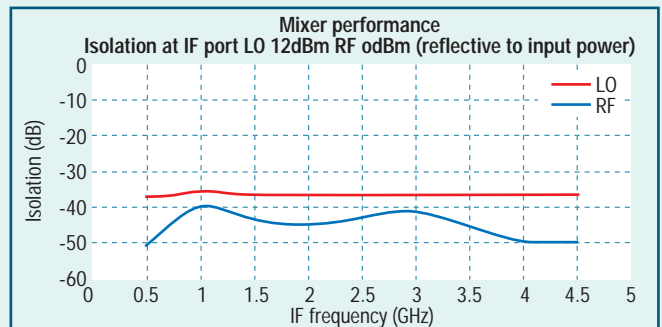


Figure 9: Mixer isolation at IF port for +12dBm LO power and 0dBm RF power

not as good as simulated (10dB too low).

Eagleware: LO isolation at RF port results were worse (10dB) than simulated. IF isolation at RF port is very good as it suggests a very low level. This is what we found in our

measurements. LO isolation at IF port were also worse (10dB) than simulated. RF isolation at IF port was about 7dB better than simulated.

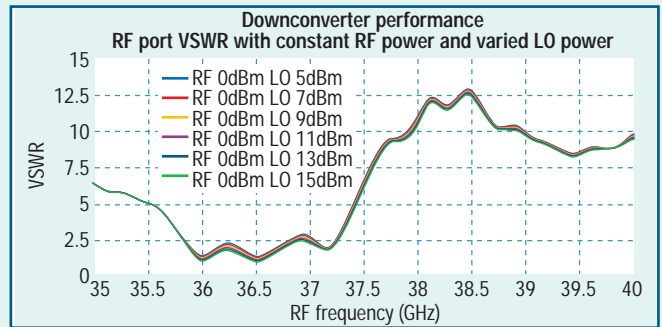
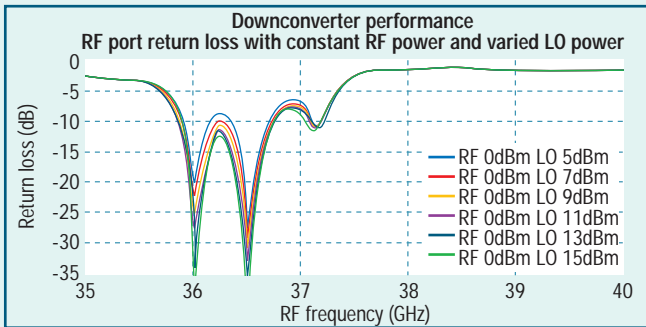


Figure 10: Downconverter (a) return loss, and (b) VSWR, at RF port with constant RF power for various LO power levels

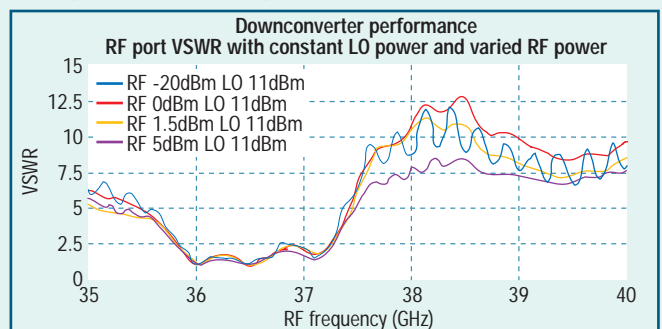
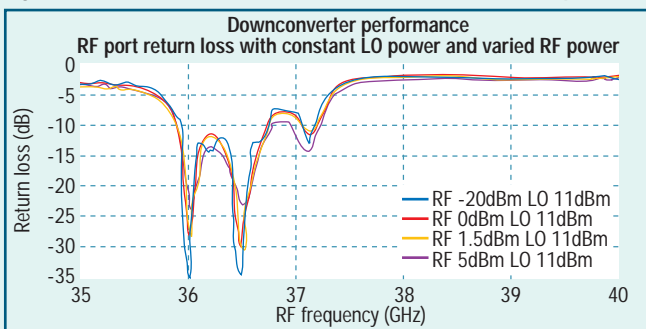


Figure 11: Downconverter (a) return loss, and (b) VSWR, at RF port with constant LO power for various RF power levels

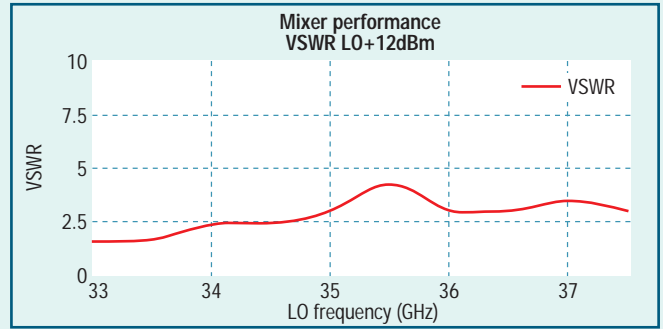
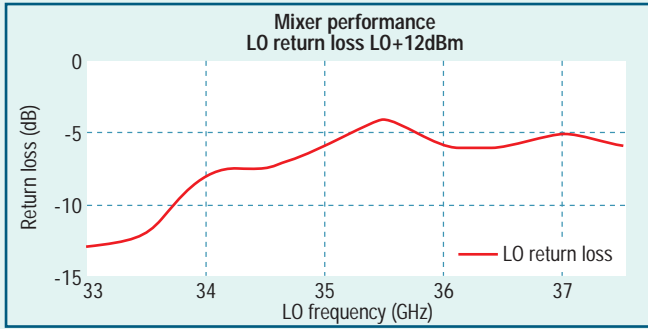


Figure 12: Mixer (a) return loss, and (b) VSWR, at LO port for +12dBm LO power level

Return loss measurements

Spurious Measurements

(a) RF = 37GHz @ -20dBm, LO = 35GHz @ 12dBm

(b) RF = 37GHz @ 0dBm, LO = 35GHz @ 12dBm

(c) RF = 37GHz @ +5dBm, LO = 35GHz @ 12dBm

Note: Other harmonics were below the minimum detectable level of the measurement setup (< -75dBc).

Harmonic (m RF x n LO)	Freq (GHz)	Level relative to wanted signal (dBc)
(1,-1)	2	0
(1,0)	37	--
(0,1)	35	3
(1,1)	72	--
(2,0)	74	--
(2,1)	109	--
(2,-1)	39	--
(2,-2)	4	--
(0,2)	70	-29
(1,2)	107	--
(-1,2)	33	--
(3,-3)	6	--
(4,-4)	8	--

Harmonic (m RF x n LO)	Freq (GHz)	Level relative to wanted signal (dBc)
(1,-1)	2	0
(1,0)	37	-36
(0,1)	35	-18
(1,1)	72	--
(2,0)	74	--
(2,1)	109	--
(2,-1)	39	--
(2,-2)	4	-43
(0,2)	70	-48
(1,2)	107	--
(-1,2)	33	-52
(3,-3)	6	-60
(4,-4)	8	--

Harmonic (m RF x n LO)	Freq (GHz)	Level relative to wanted signal (dBc)
(1,-1)	2	0
(1,0)	37	-36
(0,1)	35	-22
(1,1)	72	--
(2,0)	74	--
(2,1)	109	--
(2,-1)	39	--
(2,-2)	4	-39
(0,2)	70	-53
(1,2)	107	--
(-1,2)	33	-53
(3,-3)	6	-51
(4,-4)	8	-61

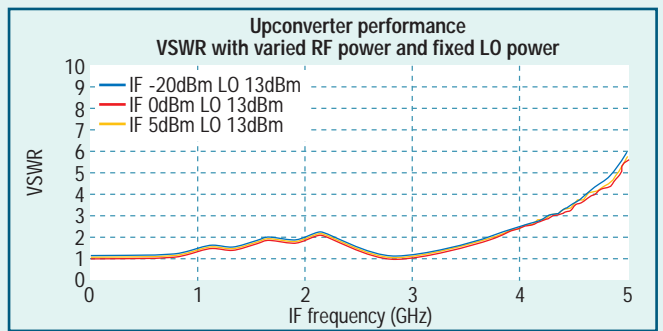
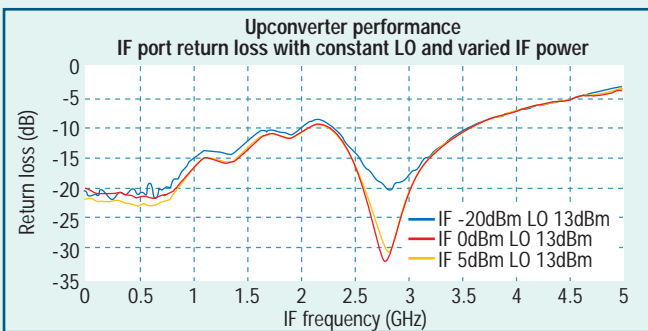


Figure 13: Upconverter (a) return loss, and (b) VSWR, at IF port with constant LO power for various IF power levels

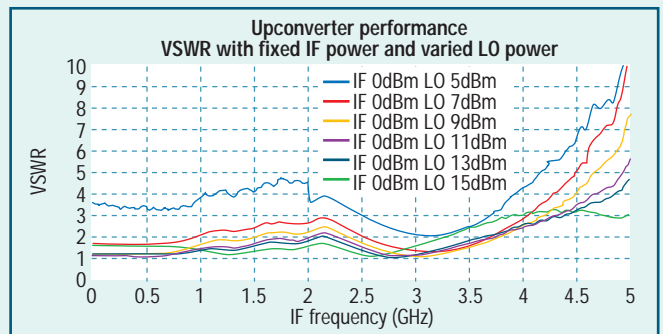
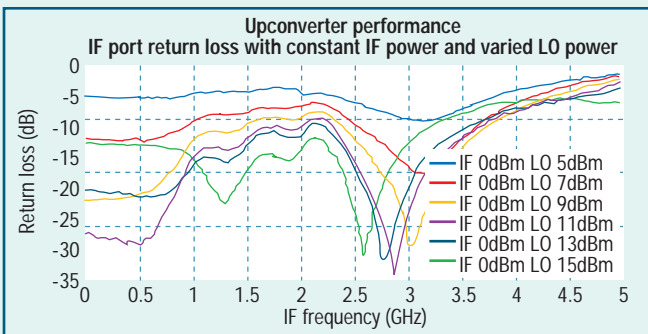


Figure 14: Upconverter (a) return loss, and (b) VSWR, at IF port with constant LO power for various RF power levels

Conclusion

Increasingly, as the lower GHz frequency spectrum becomes crowded, people are beginning to look to mm-wave frequencies for available spectrum. There is a potential wealth of applications such as broadband wireless access and automotive collision avoidance radar to name but two.

A key component for these systems will be the mixer. The rat-race mixer offers good performance at a cheap cost with the ability to integrate with other components such as MMICs. With the stringent demands that these applications will place on the designer of mm-wave components, a simulation tool which the designer can trust is invaluable. The demands placed on the simulator are great, particularly if, as in this application, there are conflicting demands from the software. The non-linear nature of the diode mixer calls for a circuit simulator, while the nature of the edge-coupled filter and hybrid ring may warrant the use of EM simulation. An efficient strategy for the successful design of this type of component is key to meeting the needs of future applications.

In conclusion, the rat-race mixer has provided a challenging problem for the EDA

vendors. All of the participants have demonstrated that their software is capable of simulating the mixer competently, although each had its individual strengths and weaknesses. We hope that this exercise will be of benefit to both users and vendors: to the former in being able to see how each simulator performs, and to the latter in understanding where improvements can be made for the future.

Errata

1. CAD Benchmark Results Part 1, November 2001 issue

APLAC section

a) The description, "...provided the material properties are homogeneous and constant over frequency..." could be ambiguous, as it implies that the APLAC models do not accept frequency dependency. The purpose of the original sentence was to emphasise the fact that materials in real life exhibit in greater or lesser extent inhomogeneity and frequency dependency that inevitably affect the measurements. In the benchmark briefing, constant values were given, and this may not exactly correspond to reality. If frequency dependencies of the material parameters had been

available, they could have been included into the APLAC simulation without problems.

b) There are two typographical errors:

■ In the LO filter paragraph, 1mm should read 1 μ m.

■ In the Hybrid ring paragraph, the letter p should in fact be the symbol π .

2. CAD Benchmark Results Part 2, December 2001/January 2002 issue AWR section

Due to administrative difficulties, several of the Figures in this section were in the wrong places with respect to the captions. A corrected version has been uploaded to the Web site on www.mwee.com, and can be downloaded in PDF format. We sincerely apologise for any confusion this may have caused.

3. CAD Benchmark Results Part 2, December 2001/January 2002 issue AC Microwave section

In table 1: 'LO' must be exchanged to 'RF'

In table 7, in the right lower number block: RF frequency = 36GHz instead of 37GHz

In figure 6: The right picture is a copy of figure 5 and can be eliminated.