APPLICATION NOTE

Phase Noise Measurements TSA5059 versus SP5659

AN99024

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Abstract

This report describes comparative measurements on phase noise behaviour between the pin and software compatible Philips TSA5059T and the Mitel SP5659 low phase noise I^2C-controlled synthesizer IC's performed on an OM5729 (pcb nr.: PR39233) demo board. Normally, the OM5729 demo board features the PHILIPS TDA8060TS QPSK Zero-IF down converter IC, the TSA5059T Low Phase Noise I^2C-controlled Synthesizer IC and TDA8083H Satellite Demodulator and Decoder IC and is targeted for medium / high symbol rates.

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Author(s):

Stefan Crijns, Evert van Capelleveen, Martijn Ophoff
Philips Semiconductors Systems Laboratory Eindhoven,
The Netherlands

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Summary

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CONTENTS

1. INTRODUCTION

This report describes comparative measurements on phase noise behaviour between the pin and software compatible Philips TSA5059T and the Mitel SP5659 low phase noise I^2C-controlled synthesizer IC's performed on an OM5729 (pcb nr.: PR39233) demo board.

2. MEASUREMENTS

This chapter describes the phase noise measurements performed on the local oscillator of the OM5729 demo board, pcb nr. PR39233. For these kind of measurements, the demo board should be set up accordingly, e.g. see paragraph 2.1.

2.1 Charge Pump Current Setting

For optimal synthesizer loop filter performance of the OM5729 the charge pump current (I_{cp}) must be set correctly in software depending on the RF frequency. These optimum values were found with the typical phase noise measurement as described in paragraph 2.2. Select in the DBUI software TUNER menu, unless specified differently:

- **I_{cp} = 555 uA for VCO frequencies below 1100 MHz.**
- **I_{cp} = 260 uA for VCO frequencies between 1100 MHz and 1200 MHz.**
- **I_{cp} = 120 uA for VCO frequencies between 1200 MHz and 1600 MHz.**
- **I_{cp} = 260 uA for VCO frequencies between 1600 MHz and 1800 MHz.**
- **I_{cp} = 555 uA for VCO frequencies between 1800 MHz and 2000 MHz.**
- **I_{cp} = 1200 uA for VCO frequencies above 2000 MHz.**

2.2 Typical Phase Noise Measurement on OM5729

Before the actual comparison measurements between the TSA5059T and the SP5659 are performed, the typical phase noise performance of the local oscillator on a standard OM5729 demo board with all possible charge pump current settings is measured. These values can be used as a reference and are needed to determine the optimum charge pump values for each RF frequency.

The measurement setup is shown in Figure 1. Measurement conditions with demo board OM5729:

- Phase Noise measured at I / Q baseband outputs (for each charge pump current) at $f_{baseband}$ = 1 MHz with a fet probe HP54701A + DC-block.
- Signal generator frequency $f_{rf} = f_{vco}$ + 1 MHz, level is - 25 dBm. The phase noise performance of used signal generator has to be significantly better than measured phase noise.
- f_{comp} = 125 kHz, prescaler TSA5059T = OFF, prescaler TDA8060 = OFF => f_{step} = 125 kHz.
- V_{agc} is manually adjusted to 500 mV_{pp} I/Q baseband output signal voltage, using an oscilloscope and a probe.
- Please take care to use noise free power supplies for accurate measurement.
- Before each measurement, the I^2C switch of TDA8083 is DISABLED in the TUNER menu of the DBUI software.

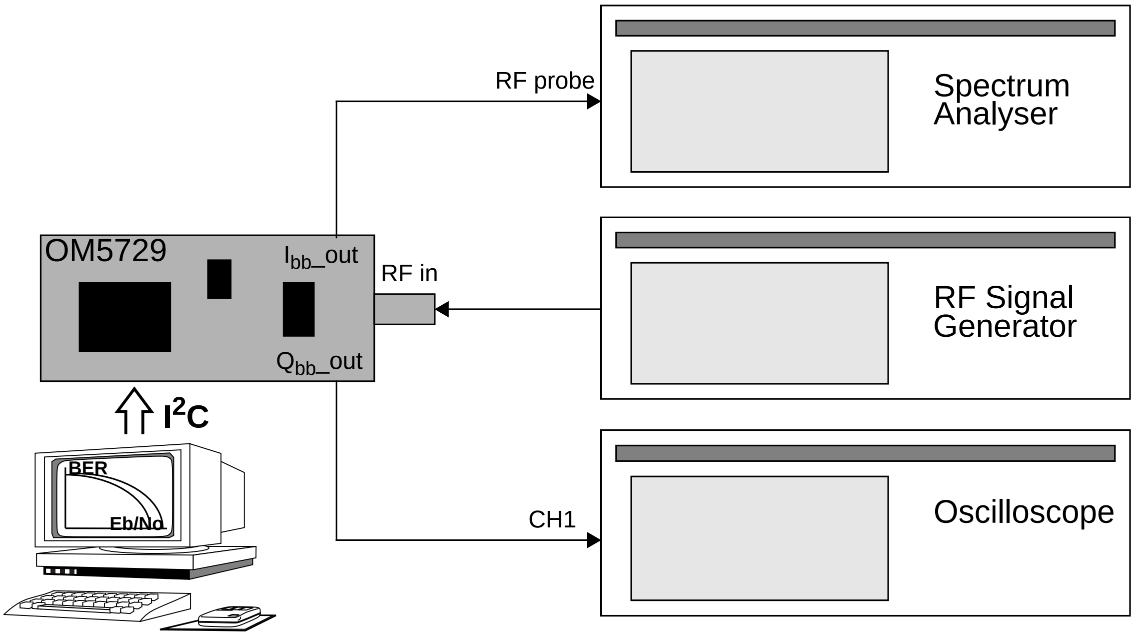

Fig.1 Phase noise measurement setup

	I_{cp} = 120 uA			I_{cp} = 260 uA		
f_{vco} [MHz]	Phase Noise [dBc/Hz @1kHz]	Phase Noise [dBc/Hz @10kHz]	Phase Noise [dBc/Hz @100kHz]	Phase Noise [dBc/Hz @1kHz]	Phase Noise [dBc/Hz @10kHz]	Phase Noise [dBc/Hz @100kHz]
950	-56.8	-81.8	-99.8	-62.0	-81.1	-99.8
1050	-56.3	-81.1	-98.4	-62.5	-80.6	-98.4
1150	-55.7	-79.1	-98.1	**-62.8**	**-78.6**	**-98.1**
1250	**-55.0**	**-76.5**	**-98.6**	-62.5	-75.6	-98.3
1350	**-54.6**	**-76.1**	**-97.6**	-59.8	-75.1	-98.1
1450	**-55.0**	**-77.0**	**-97.8**	-59.5	-76.4	-98.1
1500	**-54.5**	**-78.1**	**-98.1**	-59.2	-77.1	-98.1
1550	**-54.0**	**-79.1**	**-99.9**	-59.3	-78.6	-98.9
1650	-53.0	-79.9	-99.5	**-58.6**	**-80.0**	**-99.4**
1750	-53.8	-81.1	-99.9	**-55.2**	**-80.8**	**-99.7**
1850	-52.0	-80.9	-99.6	-53.5	-81.4	-99.4
1950	-49.7	-81.1	-99.6	-54.0	-81.4	-99.9
2050	-48.5	-80.6	-100.1	-51.8	-80.3	-100.0
2150	-50.0	-79.6	-100.1	-52.3	-80.1	-100.0

Table 1: Phase Noise measurement (typical) with I_{cp} = 120 uA and 260 uA

f_{vco} [MHz]	I_{cp} = 555 uA			I_{cp} = 1200 uA		
	Phase Noise [dBc/Hz @1kHz]	Phase Noise [dBc/Hz @10kHz]	Phase Noise [dBc/Hz @100kHz]	Phase Noise [dBc/Hz @1kHz]	Phase Noise [dBc/Hz @10kHz]	Phase Noise [dBc/Hz @100kHz]
950	**-67.0**	**-80.5**	**-99.4**	-73.2	-78.5	-99.1
1050	**-68.3**	**-79.3**	**-98.6**	-73.7	-77.4	98.6
1150	-69.0	-76.6	-98.4	-	-	-
1250	-68.7	-73.6	-97.4	-	-	-
1350	-66.3	-72.3	-97.6	-	-	-
1450	-66.1	-74.1	-98.1	-	-	-
1500	-66.3	-75.8	-98.0	-	-	-
1550	-67.3	-76.6	-99.1	-	-	-
1650	-65.3	-78.6	-99.4	-68.8	-76.9	-99.4
1750	-61.5	-80.1	-99.6	-67.1	-78.8	-99.9
1850	**-59.7**	**-80.9**	**-99.4**	-66.0	-79.8	-99.2
1950	**-56.4**	**-81.3**	**-99.9**	-62.8	-80.1	-99.8
2050	-54.0	-80.9	-100.1	**-58.2**	**-80.4**	**-100.1**
2150	-52.0	-80.3	-99.5	**-54.5**	**-80.3**	**-99.8**

Table 2: Phase Noise measurement (typical) with I_{cp} = 555 uA and 1200 uA

The reference frequency breakthrough was found to be better than -67 dBc for all measurements.

More measurements on phase noise were performed to verify the optimal charge pump current setting vs. VCO frequency. The optimum phase noise curves are chosen from the tables (bold values) and shown in Figure 2:

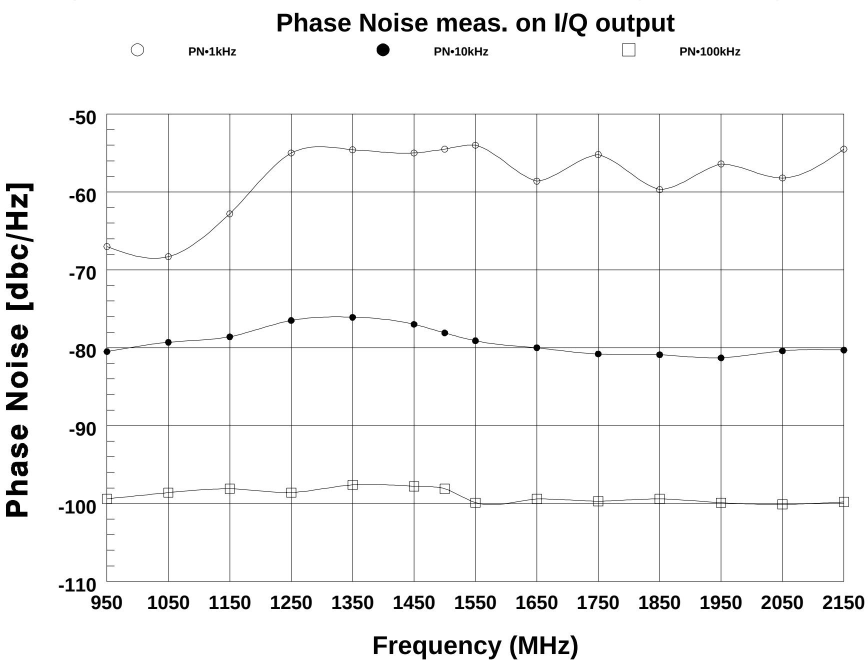

Fig.2 The phase noise performance of the synthesized VCO

2.3 Phase Noise Measurements TSA5059T versus SP5659

In this paragraph the comparison measurements between the TSA5059T and the SP5659 are described.

2.3.1 Measurement setup

The OM5729 demo board has to be modified for the use with the SP5659 + BC847 external transistor at pin 16. Normally, the OM5729 contains a TSA5059T/ES2 + BSN20 external NMOS at pin 1. The TSA5059T/ES2 sample is also reffered to as TSA5059T/C1.
In Figure 3 the two setups are shown which have been used to compare the phase noise behaviour.

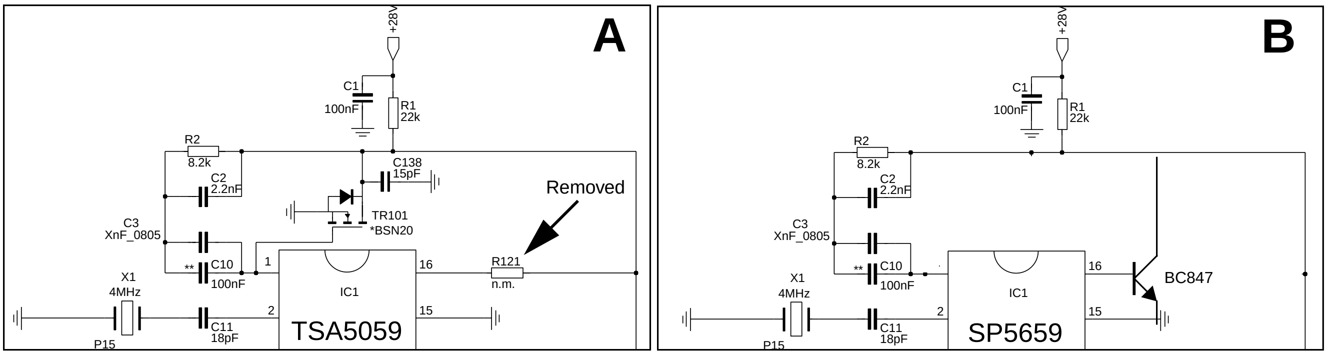

Fig.3 OM5729 original application for TSA5059 usage (A) and modified application for SP5659 usage (B)

2.3.2 Measurement condition

Measurement condition with demo board OM5729:

- Phase Noise measured at I / Q baseband outputs at $f_{baseband}$ = 100 Hz up to 100 kHz with the optimum charge pump current as found in Table 1 and Table 2 .
- Signal generator frequency $f_{rf} = f_{vco}$ + 1 MHz, level is - 25 dBm. The phase noise performance of used signal generator has to be significantly better than measured phase noise.
- f_{comp} = 125 kHz, prescaler TSA5059 / SP5659 = OFF, prescaler TDA8060 = OFF => f_{step} = 125 kHz, unless specified differently.
- V_{agc} is manually adjusted to 500 mV_{pp} I/Q baseband output signal voltage.
- Before each measurement, the I^2C switch of TDA8083 is DISABLED in the TUNER menu of the DBUI software.

2.3.3 Measurement results

- In Figure 4 and Figure 5 the Phase Noise results at fvco = 950 MHz (lowest RF frequency) are compared between the TSA5059T and the SP5659.
- In Figure 6 and Figure 7 the Phase Noise results at fvco = 1350 MHz (highest K_{vco} frequency) are compared between the TSA5059T and the SP5659.
- In Figure 8 and Figure 9 the Phase Noise results at fvco = 1500 MHz (middle of the frequency band) are compared between the TSA5059T and the SP5659.
- In Figure 10 and Figure 11 the Phase Noise results at fvco = 1850 MHz are compared between the TSA5059T and the SP5659.
- In Figure 12 and Figure 13, Figure 14 and Figure 15 the Phase Noise results at fvco = 2150 MHz (highest RF frequency) are compared between the TSA5059T with standard settings and the SP5659 with three different settings regarding prescaler and f_{comp}.

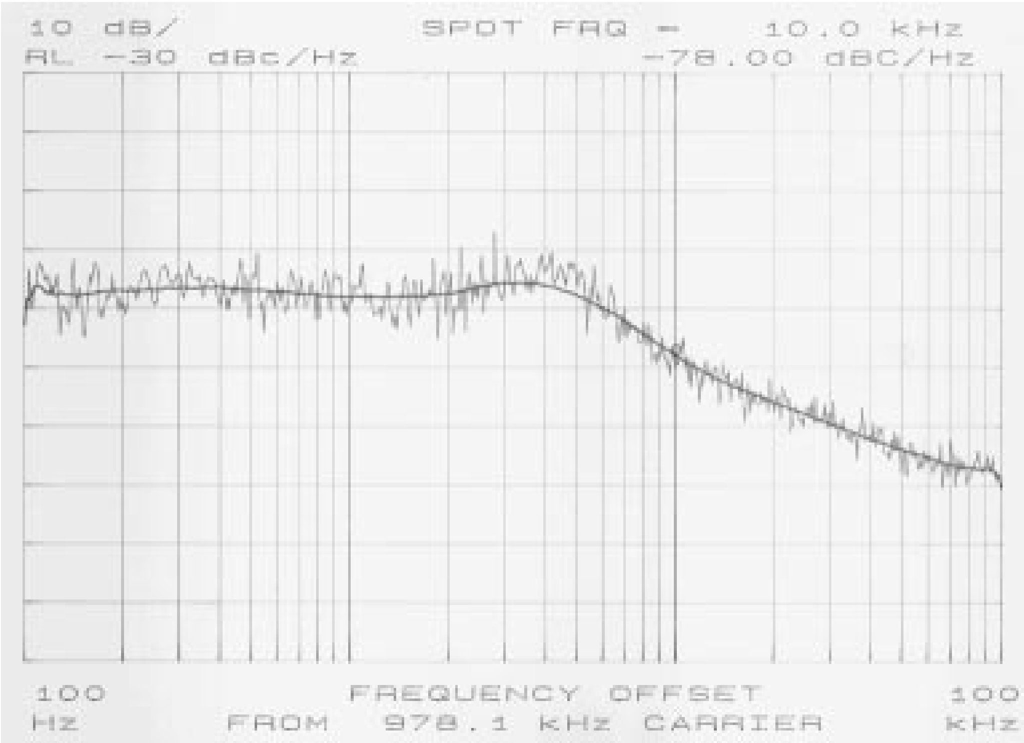

Fig.4 Phase Noise performance TSA5059T/ES2 + BSN20 NMOS at f_{vco} = 950 MHz and I_{cp} = 555 uA

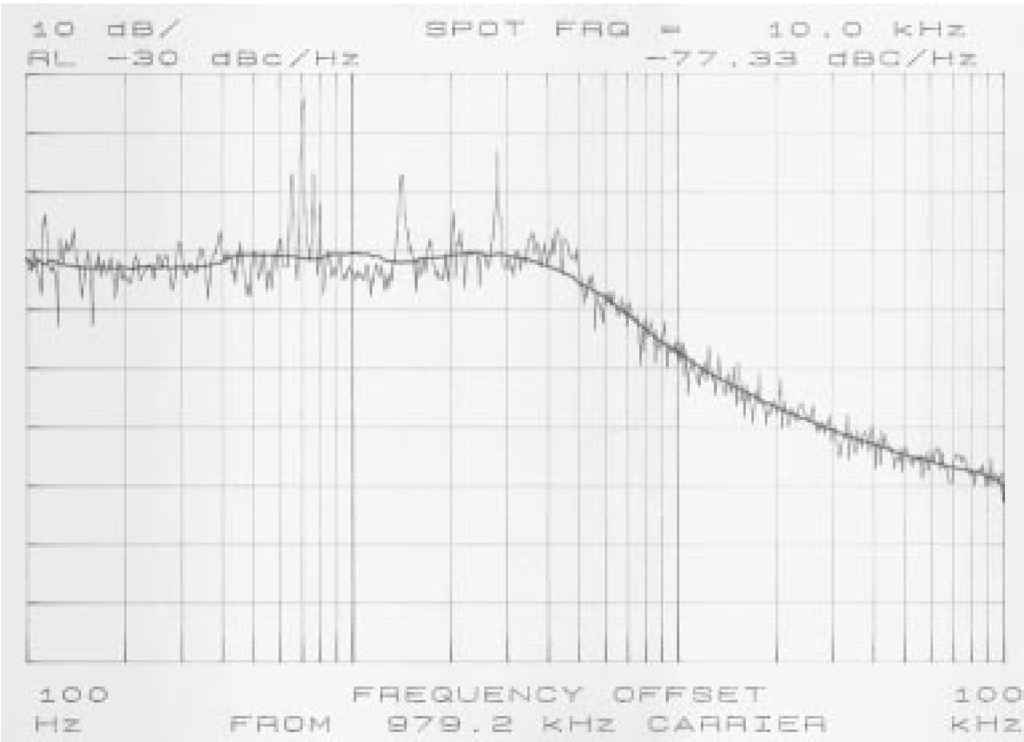

Fig.5 Phase Noise performance SP5659 + BC847 transistor at f_{vco} = 950 MHz and I_{cp} = 555 uA

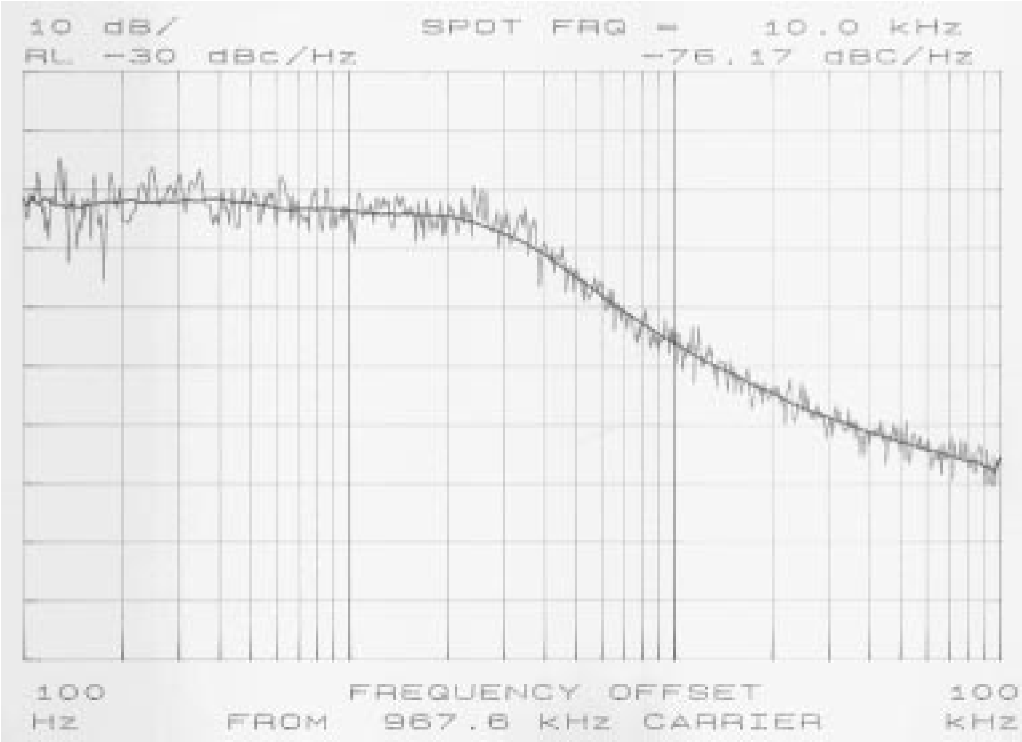

Fig.6 Phase Noise performance TSA5059T/ES2 + BSN20 NMOS at f_{vco} = 1350 MHz and I_{cp} = 120 uA

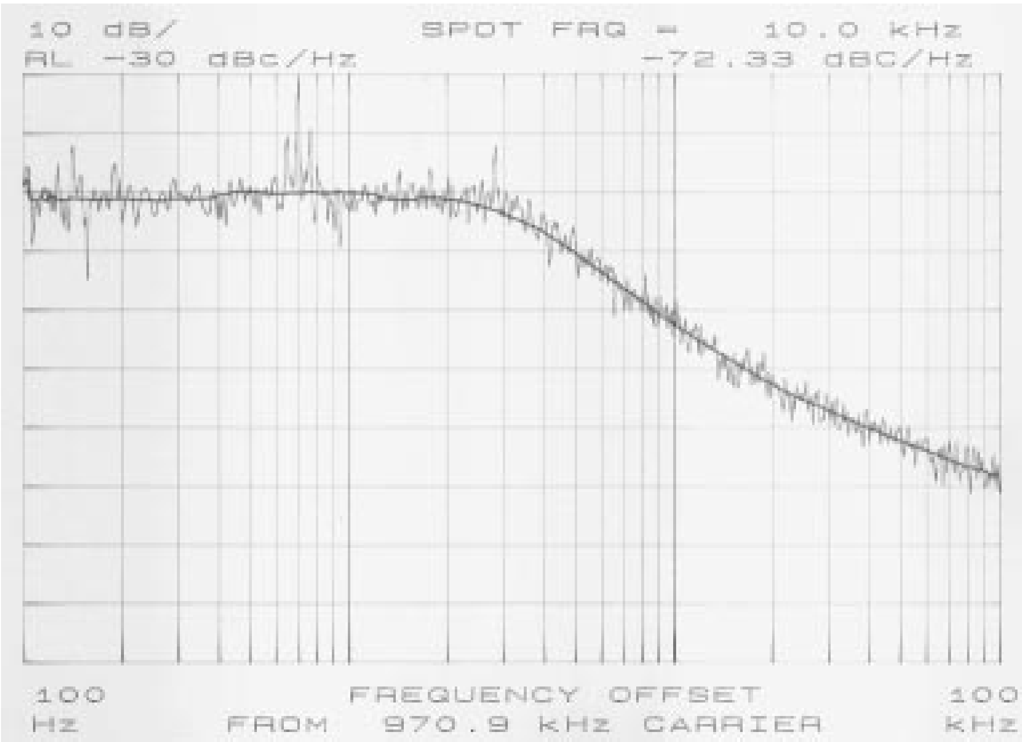

Fig.7 Phase Noise performance SP5659 + BC847 transistor at f_{vco} = 1350 MHz and I_{cp} = 120 uA

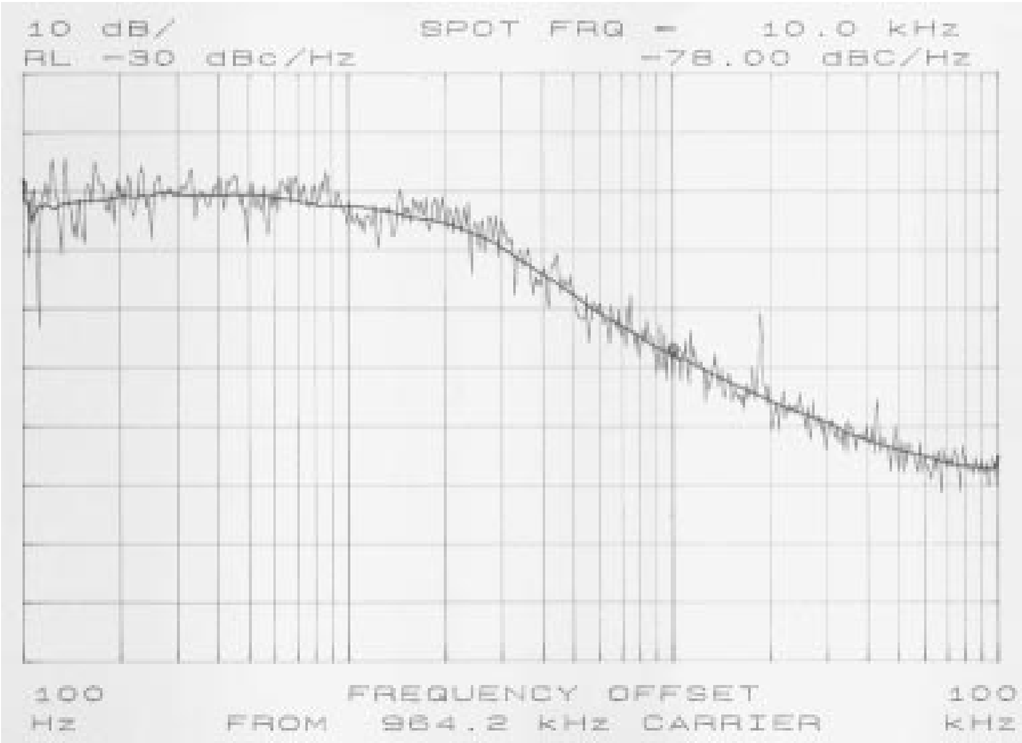

Fig.8 Phase Noise performance TSA5059T/ES2 + BSN20 NMOS at f_{vco} = 1500 MHz and I_{cp} = 120 uA

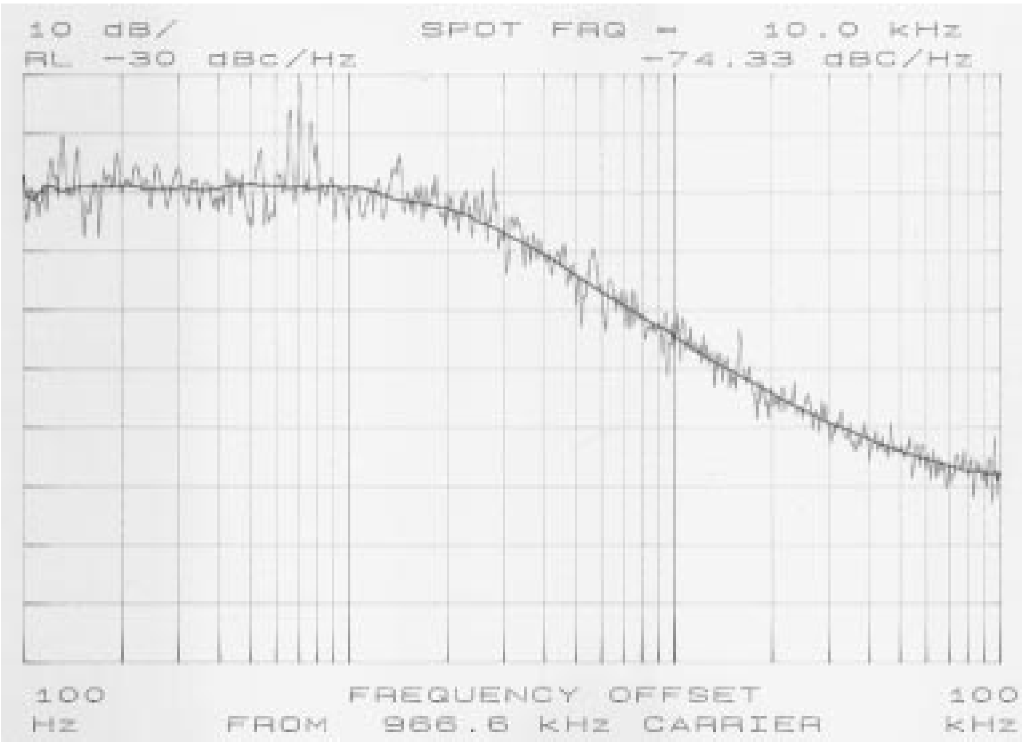

Fig.9 Phase Noise performance SP5659 + BC847 transistor at f_{vco} = 1500 MHz and I_{cp} = 120 uA

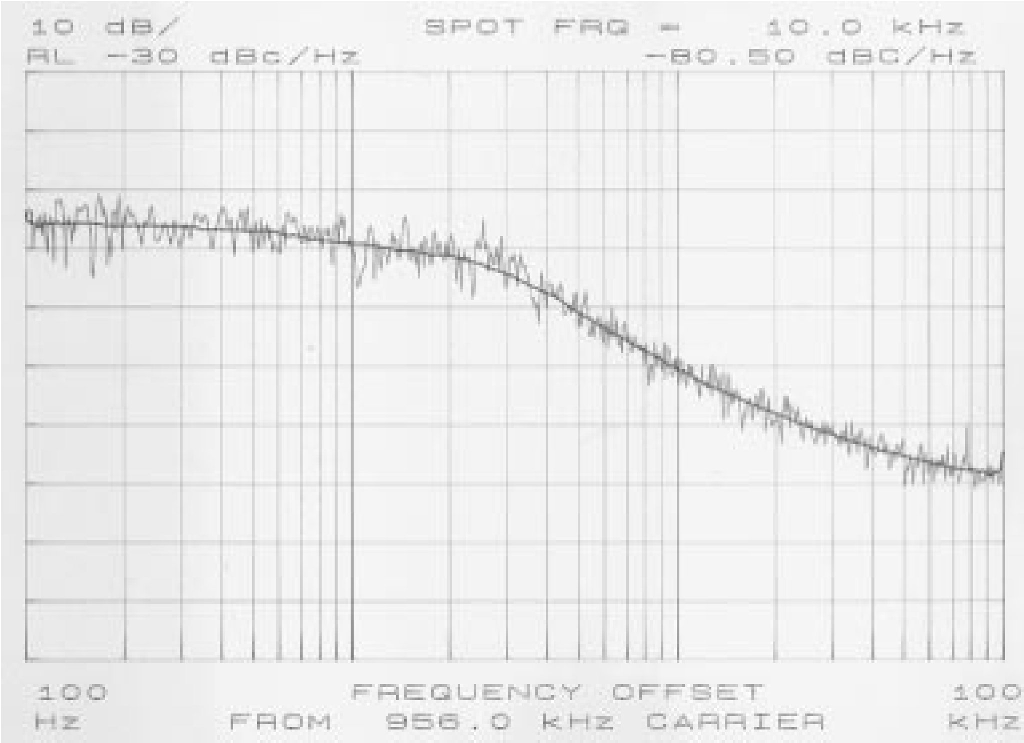

Fig.10 Phase Noise performance TSA5059T/ES2 + BSN20 NMOS at f_{vco} = 1850 MHz and I_{cp} = 555 uA

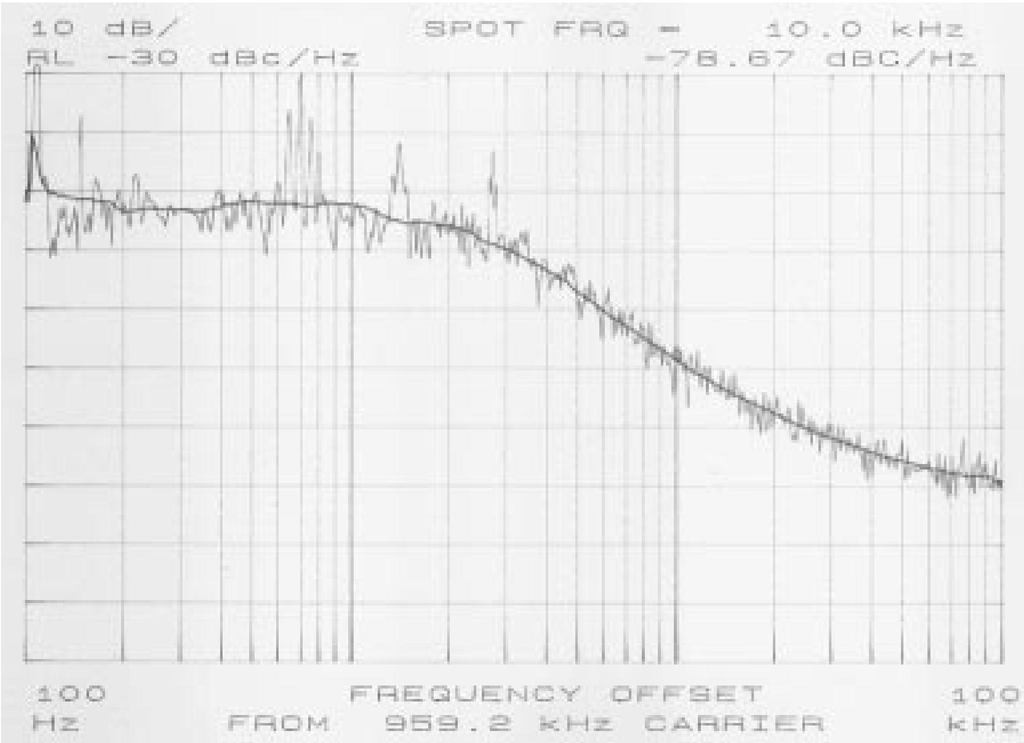

Fig.11 Phase Noise performance SP5659 + BC847 transistor at f_{vco} = 1850 MHz and I_{cp} = 555 uA

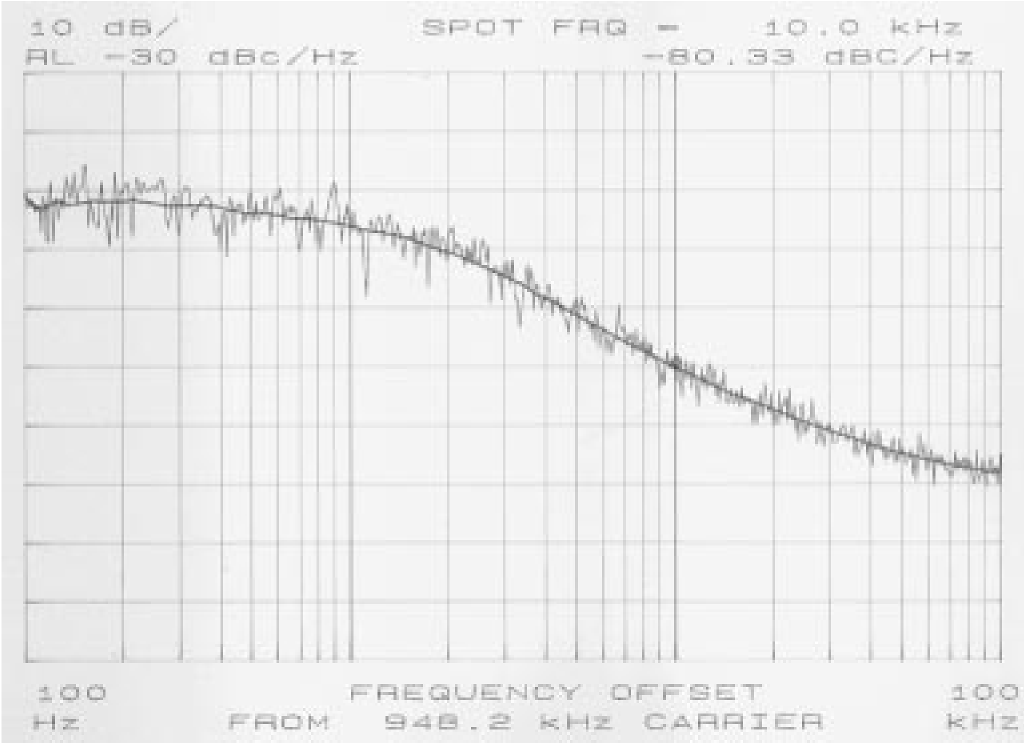

Fig.12 Phase Noise performance TSA5059T/ES2 + BSN20 at f_{vco} = 2150 MHz and I_{cp} = 1200 uA.

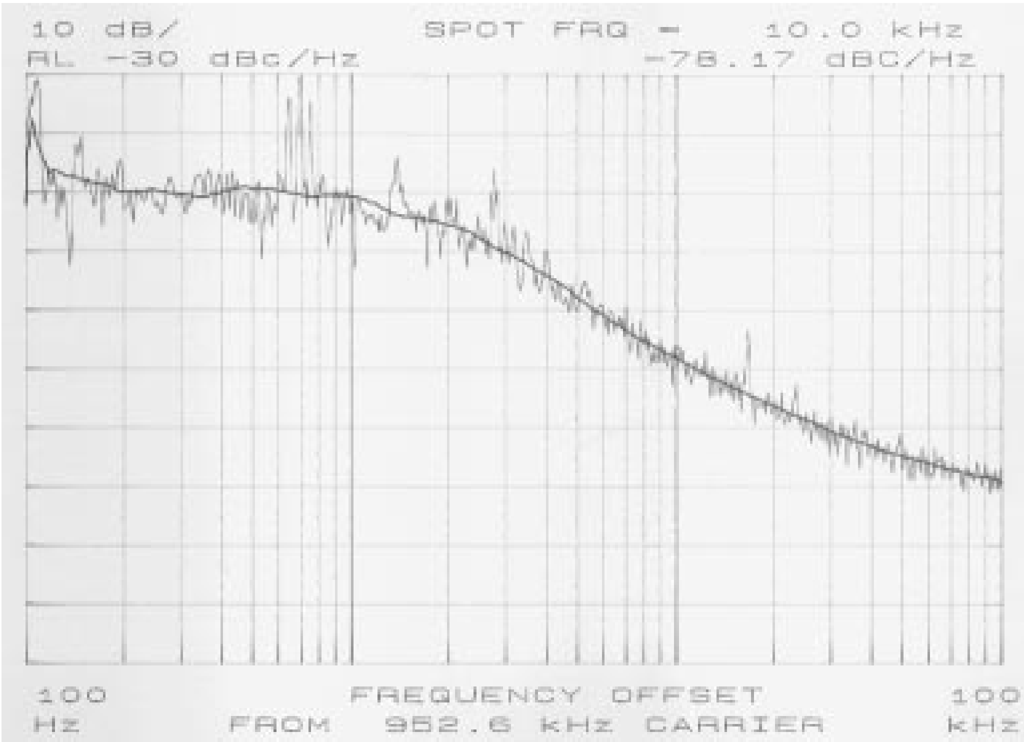

Fig.13 SP5659 + BC847 at f_{vco} = 2150 MHz, I_{cp} = 1200 uA, f_{comp} = 125 kHz, prescaler SP5659 = OFF, f_{step} = 125 kHz

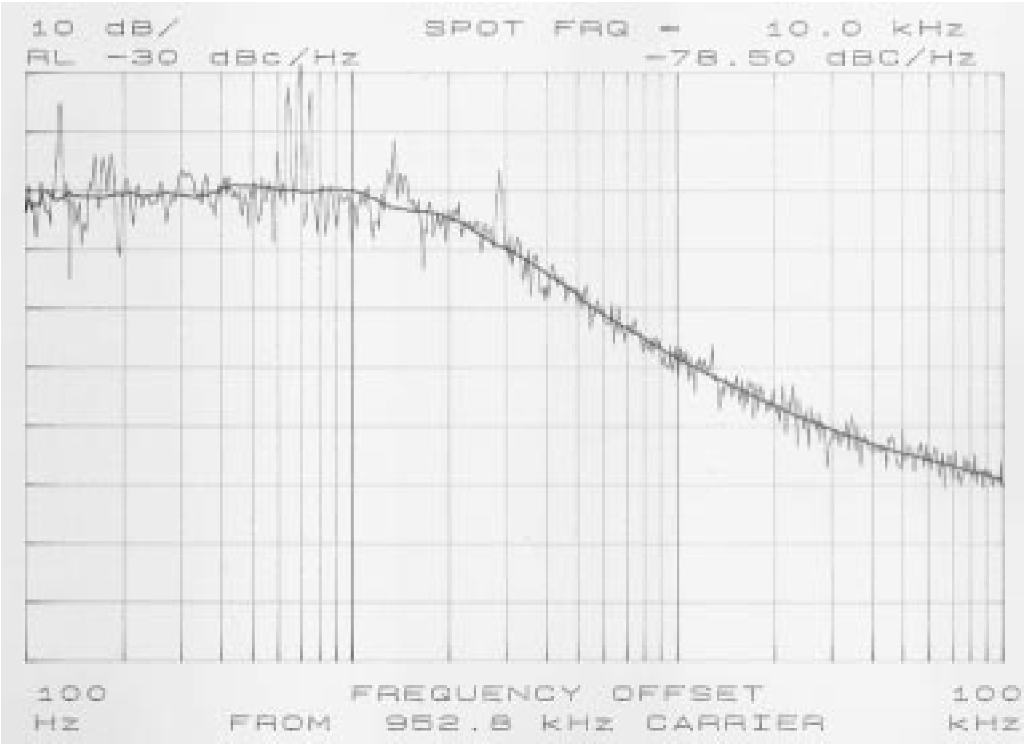

Fig.14 SP5659 + BC847 at f_{vco} = 2150 MHz, I_{cp} = 1200 uA, f_{comp} = 125 kHz, prescaler SP5659 = ON, f_{step} = 250 kHz

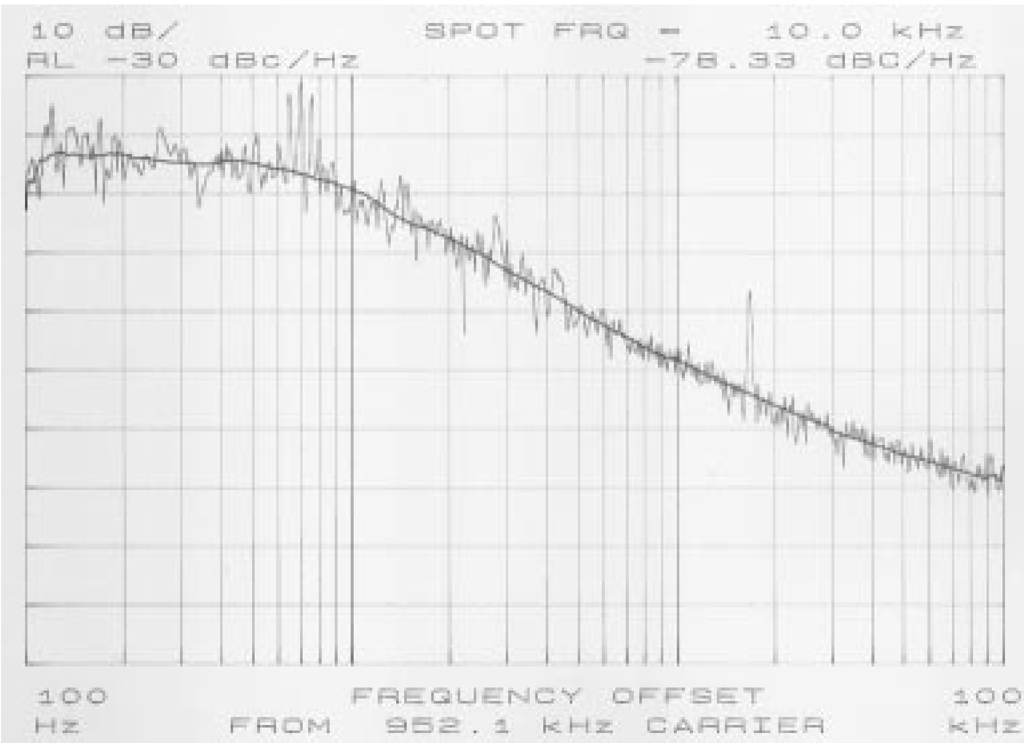

Fig.15 SP5659 + BC847 at f_{vco} = 2150 MHz, I_{cp} = 1200 uA, f_{comp} = 62.5 kHz, prescaler SP5659 = ON, f_{step} = 125 kHz

In Table 3 the numerical values of the phase noise graphs and the loop filter bandwidths of the TSA5059T and the SP5659 are shown. In the third column the difference in performance between the TSA5059T and the SP5659 is derived.

f_{vco}	TSA5059T + BSN20				SP5659 + BC847				Δ (TSA5059T - SP5659)			
	Loop	Phase Noise [dBc/Hz]			loop	Phase Noise [dBc/Hz]			loop	Phase Noise [dBc/Hz]		
[MHz]	B.W. [kHz]	@ 1 kHz	@ 10 kHz	@ 100 kHz	B.W. [kHz]	@ 1 kHz	@ 10 kHz	@ 100 kHz	B.W. [kHz]	@ 1 kHz	@ 10 kHz	@ 100 kHz
950	6.0	-67.0	-78.0	-99.0	4.3	-61.0	-77.3	-100	+1.7	-6.0	-0.7	+1.0
1350	2.5	-54.0	-76.2	-97.0	2.5	-50.0	-72.3	-98.0	0	-4.0	-3.9	+1.0
1500	1.5	-53.0	-78.0	-97.0	1.5	-49.5	-74.3	-97.5	0	-3.5	-3.7	+0.5
1850	1.2	-59.5	-80.5	-98.0	1.2	-52.5	-78.7	-99.0	0	-7.0	-1.8	+1.0
2150 Figure 14 Figure 15	0.8	-56.0	-80.3	-97.5	1.0 1.5 1.0	-51.0 -50.0 -49.5	-78.2 -78.5 -78.3	-98.0 -99.0 -98.5	-0.2	-5.0	-2.1	+0.5

Table 3: Phase noise and loop bandwidth comparison results

The comparison results of Table 3 show that the TSA5059T has a consistent better phase noise performance within the loop bandwidth (1 kHz) and outside the loop bandwidth (10 kHz) compared to the SP5659, due to the better Synthesizer Noise Floor (SNF) of the TSA5059T. At 100 kHz distance, where the natural LO phase noise is measured, the TSA5059T + BSN20 shows a slight degradation in phase noise compared to the SP5659 of about 1 dB.

As an example:
At f_{vco} = 950 MHz, the loop BW of the TSA5059T is larger compared to the SP5659 (6 kHz i.s.o. 4.3 kHz), most probably due to differences in loop gain. This larger loop BW normally means less suppression of noise outside the loop BW, so one would expect to have a worse value for phase noise at e.g. 10 kHz distance from the carrier. In fact, the measurement results at this point show to have an even better phase noise behaviour (about 0.7 dB) at 10 kHz distance for the TSA5059T compared to the SP5659.

3. CONCLUSION

The comparative phase noise measurement results between the Philips TSA5059T/ES2 + BSN20 and the Mitel SP5659 + BC847 low phase noise I^2C-controlled synthesizer IC's, performed on a zero-IF digital satellite-TV receiver demo board OM5729, show a consistent better phase noise performance within the loop bandwidth (1 kHz) and outside the loop bandwidth (10 kHz) for the TSA5059T compared to the SP5659, due to the better Synthesizer Noise Floor (SNF) of the TSA5059T.