AN11698

BFU910F FE for Ku band Universal Single LNB applications

Rev. 1 — 8 December 2015 **Application note**

Document information

Info	Content
Keywords	BFU910F, Frontend, Ku band, LNA, LNB
Abstract	This Application Note describes the reference design of a two stage LNA Frontend for Ku band Universal Single LNBs based on BFU910F. BFU910F in combination with LS9105 bias device, with its very good noise figure, high gain, low current, simplicity of the bias circuitry and small size, can provide a very competitive solution for Ku band LNB Frontend applications

Revision history

Rev	Date	Description
1	20151208	First publication

Contact information

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1. Introduction

BFU910F is a discrete SiGe-C HBT. It is produced in QuBIC4mmW Gen9 which is NXP's newest BiCMOS platform process for high performance RF applications in the mmWave domain. The extrinsic base resistance has been decreased by several methods, most importantly by self-alignment of the extrinsic base connection to the emitter. As a result, lower base resistance, lower noise and higher cut off frequency have been achieved. The new process is robust and manufacturable and it results in improved noise performance without significantly adding to process complexity

BFU910F has outstanding NF and gain performances at Ku band frequencies, achieved at relatively low bias current. Using these assets, BFU910F has been brought to market to replace GaAs pHEMTs for Ku band LNA applications

NE3503 from Renesas, one of the most popular pHEMT on the market, is being used as comparison reference for BFU910F throughout this document.

2. General description

2.1 Basic concept

LNBs are electronic devices mounted outdoor on the satellite dishes and used for satellite TV reception. Basically it is a receiver that ensures the required sensitivity level for the very weak input signals and down-converts the block of microwave frequencies (MW) to a lower block of intermediate frequencies (IF) simultaneously boosting the power level.

Fig 1 below presents the constitutive elements of an LNB. These can be grouped into three major blocks generically named Probes, Frontend and DNC (down-converter). The Probes block incorporates all microwave / mechanical components of the receiving chain - feed-horn, waveguide and antenna probes – responsible to pick-up the microwave signal from the dish and to bring it to the inputs of the LNB board. The Frontend block is a two input / single output / two stage amplification chain that ensures the sensitivity of the LNB. The DNC down-converts the microwave frequencies and boosts the power level.

The Frontend (FE) is the core stage that quantifies the LNB noise performance change if GaAs pHEMTs are replaced with NXP's BFU910F SiGe HBTs. From this perspective the most relevant parameters for the FE are the noise and the gain.

The BFU910F Frontend reference design also introduces the new bias and control IC from LiSion, LS9105. With features fully in line with the concept of an HBT FE, it also contributes to the small size, low current and simplicity achievements of the design.

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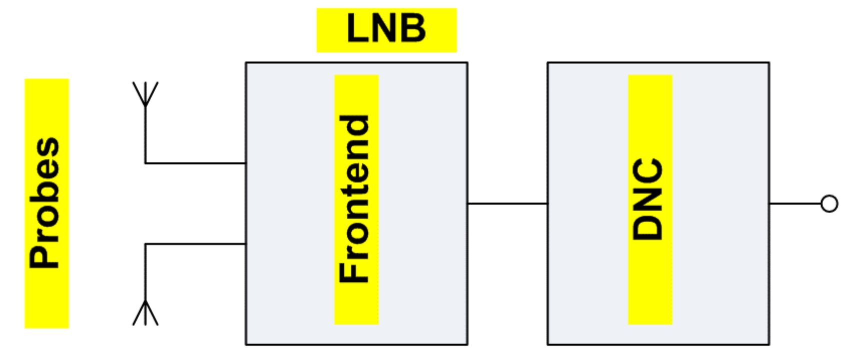
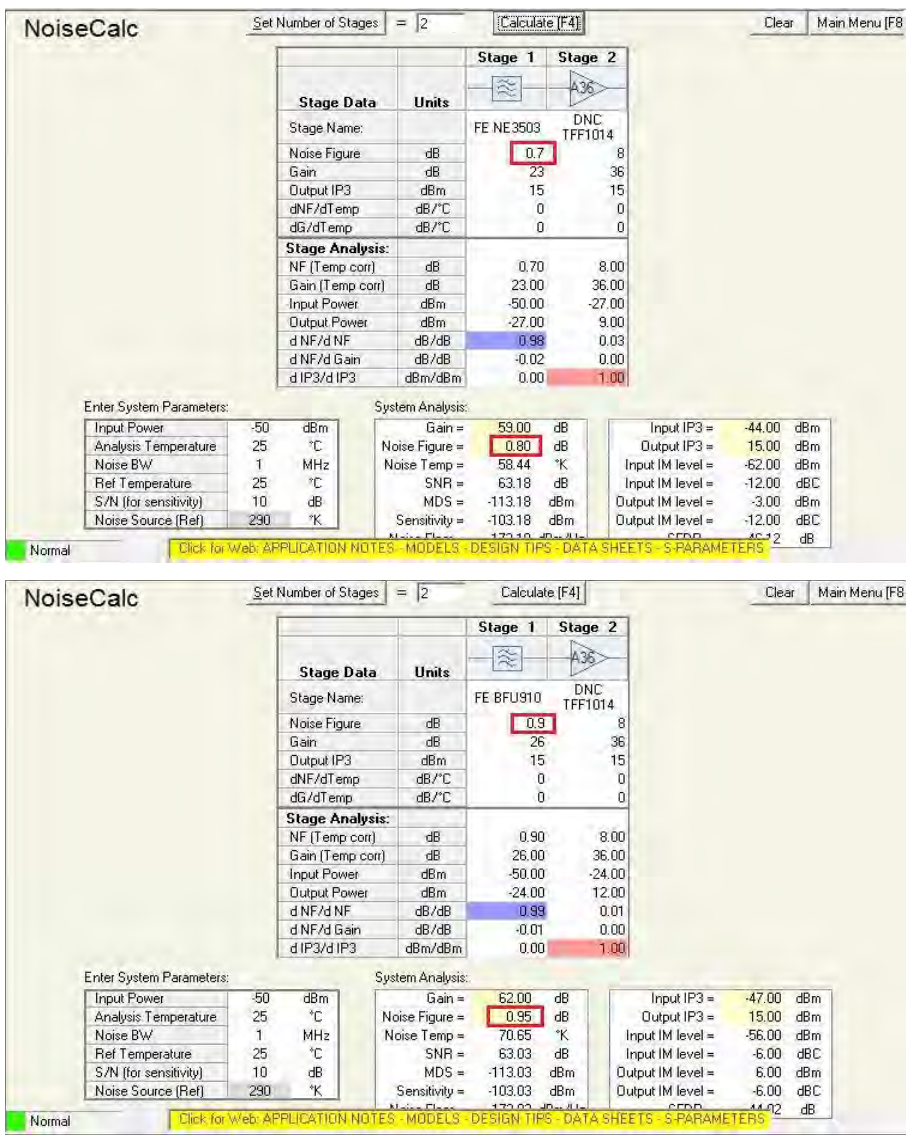


Fig 1. LNB's constitutive blocks

2.2 System

In LNB systems the FE has to compensate for the much higher NF of the DNC. Its gain is then a very important figure of merit. The system analysis in Fig 2 highlights the benefits of a higher gain device. The NF and gain inputs for the FE are simulation data: 0.7/23dB for NE3503 and 0.9/26dB for BFU910F

The key point of the cascade noise figure analysis below is, in comparison with NE3503 FE, BFU910F FE ensures less NF degradation at LNB level: 0.05dB vs. 0.1dB.



BFU910F FE ensures less NF degradation: 0.05dB in comparison with 0.1dB

Fig 2. System analysis for BFU910F FE vs NE3503 FE LNBs

3. Objective

The main objectives for the development of the BFU910F FE are:

- Create a reference design for a Ku band Universal Single LNB FE based on BFU910F
- Design the FE based on an LNB structure such that its layout and mechanical solutions can be easily translated into the higher level development of the LNB.
- Replace the **I** and **L** probes with 50Ω SMA connectors. Probes quality is not relevant to define the FE performance
- Incorporate LiSion's LS9105, the new bias and control IC specially produced to accommodate BJT FEs that do not require a negative bias supply

This Application Note describes the reference design of the two stage LNA FE for Ku band Universal Single LNBs based on BFU910F, highlighting its benefits over the NE3503 pHEMT FE.

4. Requirements - ASTRA standard for Universal Single LNBs

LNB Characteristics

The following characteristics apply to the part of the ASTRA Universal Single LNB between the input wave-guide and the output socket.

No.	Parameter			Value Min.	Typ.	Max.	Unit
1	Input Frequency	Low Band		10.70 to 11.70			GHz
		High Band		11.70 to 12.75			GHz
2	Output Frequency	Low Band		950 to 1950			MHz
		High Band		1100 to 2150			MHz
3	Local Oscillator Frequency	Low Band		9.745	9.750	9.755	GHz
		High Band		10.595	10.600	10.605	GHz
4	Phase Noise	Low Band and High Band	At 1 kHz offset			-50	dBc/Hz
			At 10 kHz offset			-75	dBc/Hz
			At 100 kHz offset			-95	dBc/Hz
			At 1 MHz offset			-105	dBc/Hz
			At ≥ 10 MHz offset			-115	dBc/Hz
5	Conversion Gain			50		60	dB
6	Gain Ripple	in 26 MHz Bandwidth				1	dB
		Low Band			3	5	dB
		High Band			3	5	dB
7	Noise Figure	Low Band			1.1	1.3	dB
		High Band			1.3	1.5	dB
8	Image Rejection			40			dB
9	1 dB Compression Point			0			dBm
10	3rd Order Intermodulation (Two Tones)	Intercept Point		10			dBm
11	Output Impedance				75		Ω
12	Return Loss			8			dB
13	Cross-Polar Rejection			20			dB
14	In Band Spurious				-65	-60	dBm
15	LNB Supply Voltage (Control Signal)	Vertical Polarisation (Signal Ca)		11.5		14.0	V
		Horizontal Polarisation (Signal Cb)		16.0		19.0	V
16	High Band Selection (Control Signal Cc)	Frequency		18	22	26	kHz
		Duty Cycle		40	50	60	%
		Peak to Peak Voltage		0.4	0.6	0.8	V
		Transition Time		5	10	15	µs
		Load Impedance at 22 kHz		70			Ω
17	Current Consumption per LNB				100	200	mA

Table 1: LNB Characteristics

Astra's typical NF target for the LB / HB LNB is 1.1 respectively 1.3dB. Corresponding maximum values are 1.3 / 1.5dB

Fig 3. Astra requirements for the Ku band Universal Single LNB

5. FE reference design using BFU910F

5.1 Block Diagram

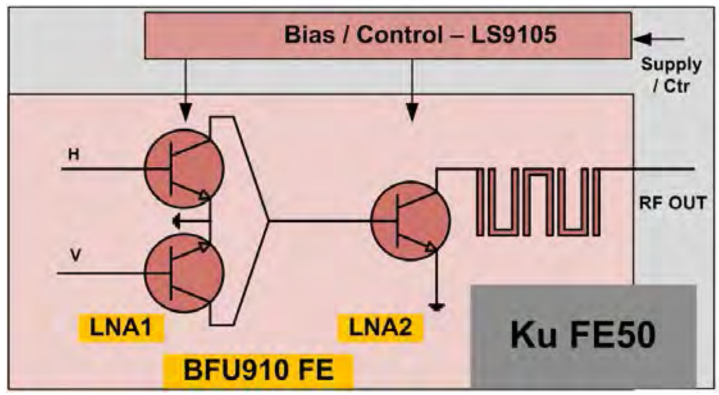


Fig 4. Block diagram for BFU910F FE with RF inputs on 50Ω SMA connectors

5.2 FE Schematic

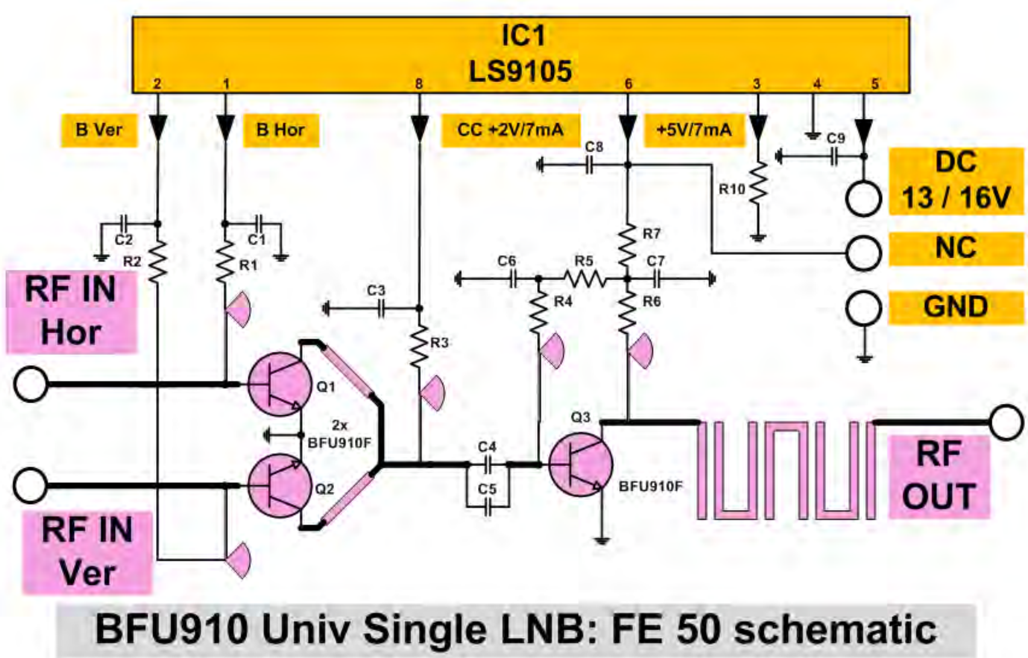


Fig 5. Schematic diagram for BFU910F FE with RF inputs on 50Ω SMA connectors

5.3 FE board layout

5.3.1 Printed circuit board details

The PCB material used for the board of this FE is Rogers RO4003. The PC board consists of: 35um top metal layer, 0.5mm thickness low loss dielectric layer with ε_R = 3.38 and TanD=0.0024, and 35um bottom metal layer. Rogers RO4233 or Isola IS680-338 material can also be used.

5.3.2 Layout top layer view

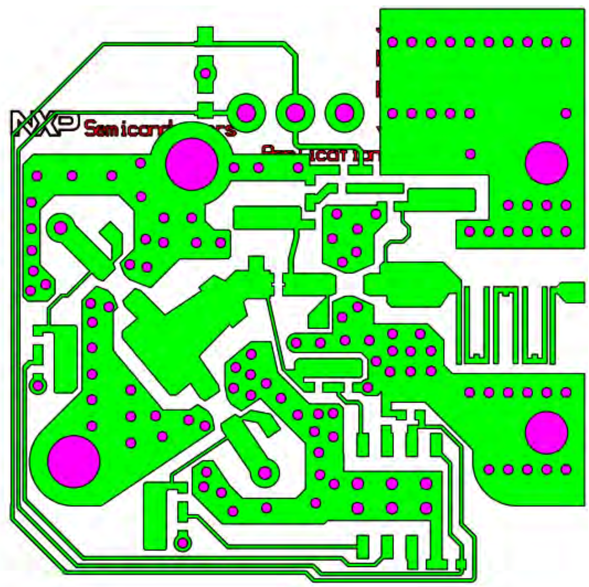


Fig 6. BFU910F FE layout top layer

5.3.3 Layout bottom layer view

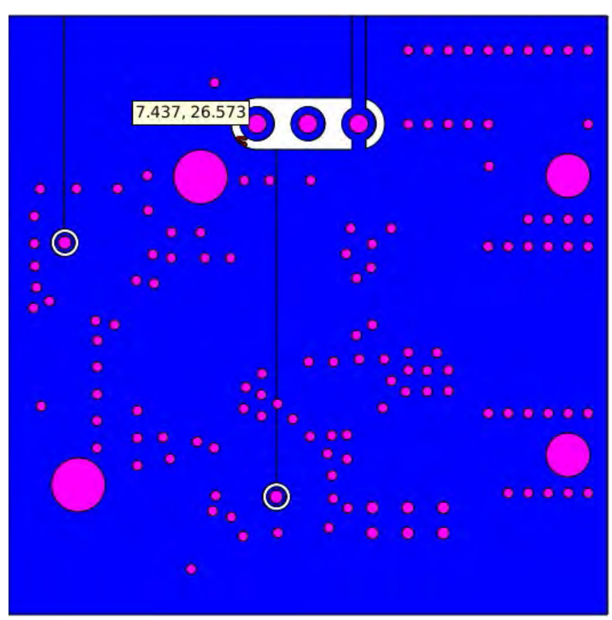


Fig 7. BFU910F FE layout bottom layer

5.4 Mechanics

The FE top-lid and base bodies are AL 35mm x 30mm x 7mm. Their mechanical drawings and 3D view are in Fig 8, Fig 9, and Fig 10 respectively

5.4.1 Top-lid drawing

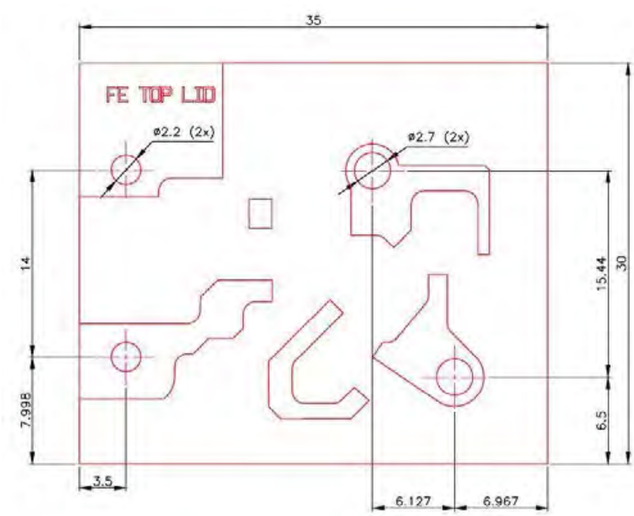


Fig 8. Mechanical drawing for top-lid BFU910F FE

5.4.2 Base drawing

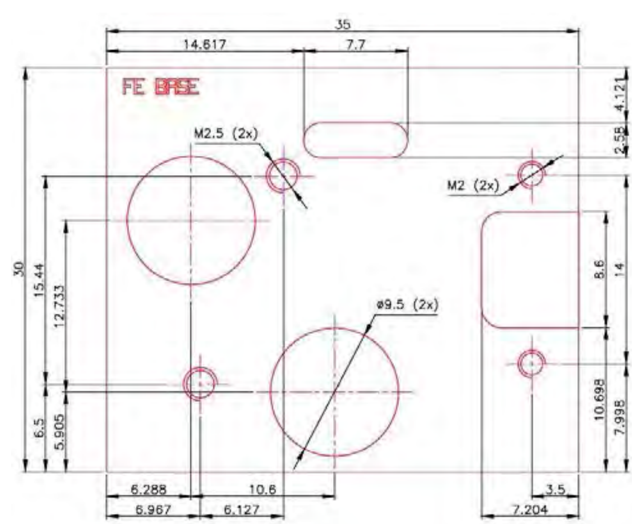


Fig 9. Mechanical drawing for base BFU910F FE

5.4.3 FE mechanics 3D view

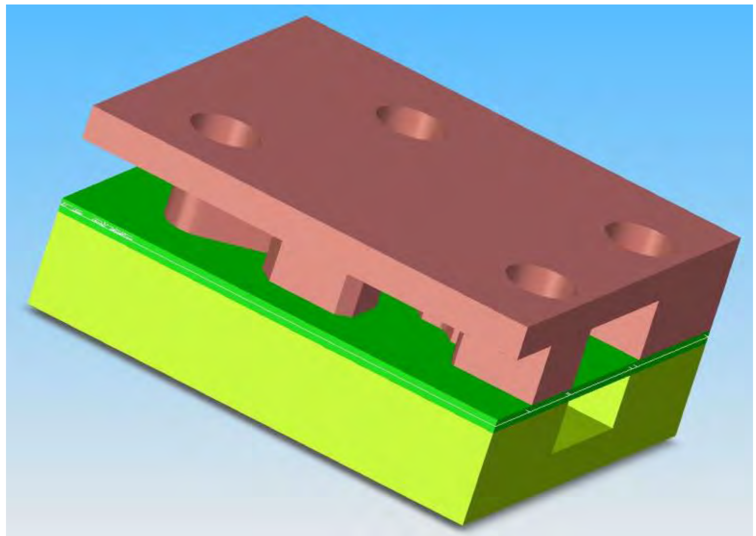


Fig 10. FE mechanics 3D view

5.5 View and ports functions

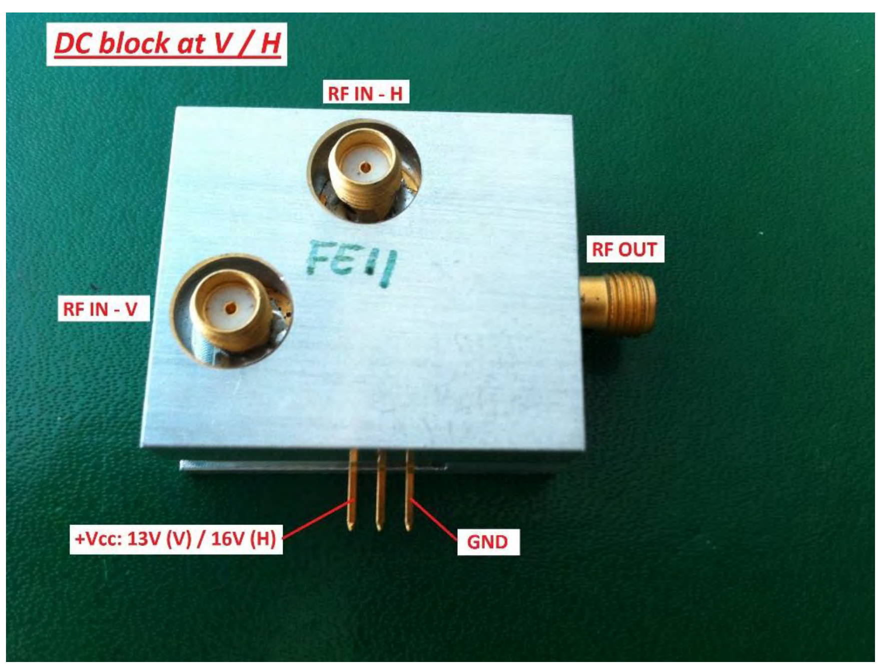


Fig 11. View and ports functions for BFU910F FE

5.6 BOM and assembly

5.6.1 BOM

Table 1. BOM for BFU910F FE

Component	Description	Value	Qty	MFG /size
C1, C2, C3, C6, C7	Capacitor	470pF / X7R	5	0402
C10, C11	Capacitor	100nF / X7R	2	0402
C4, C5	Capacitor	0.3pF	2	Murata GRM15 / 0402
C8, C9	Capacitor	100nF / Y5V	2	0603
R1, R2, R4	Resistor	100Ω	3	0402
R3, R6	Resistor	10Ω	2	0402
R7	Resistor	390Ω	1	0402
R5	Resistor	270k	1	0402
R8	Resistor	27K	1	0402
R9	Resistor	100k	1	0402
Q1, Q2, Q3	MW RF transistor	BFU910F	3	NXP / SOT343F
IC1	LNB Bias/Ctr IC	LS9105	1	LiSion / HTSOP-8
X1, X2	SMA RF connector bottom mounting	50Ω	2	Giga-lane / PSF-S01
X3	SMA RF connector side mounting	50Ω	1	Giga-lane / PSF-S01
X4	DC connector	1row / 3way	1	Molex/
PCB	Printed circuit board	RO4233 / RO4003	1	Rogers / 30mm x 30mm

5.6.2 Assembly FE

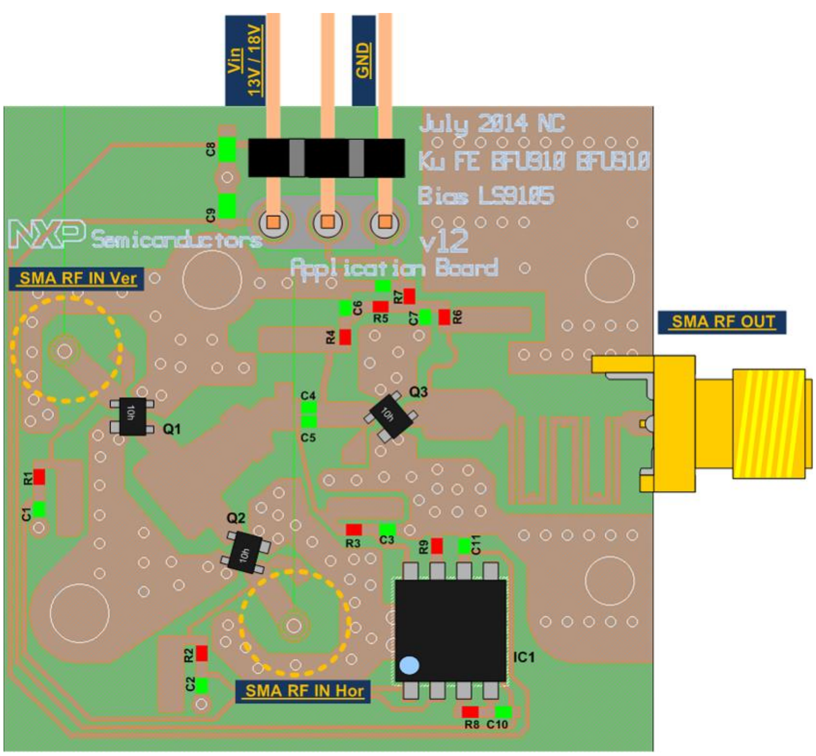


Fig 12. Assembly drawing for BFU910F FE

6. Performance and measurement results

6.1 Summary results

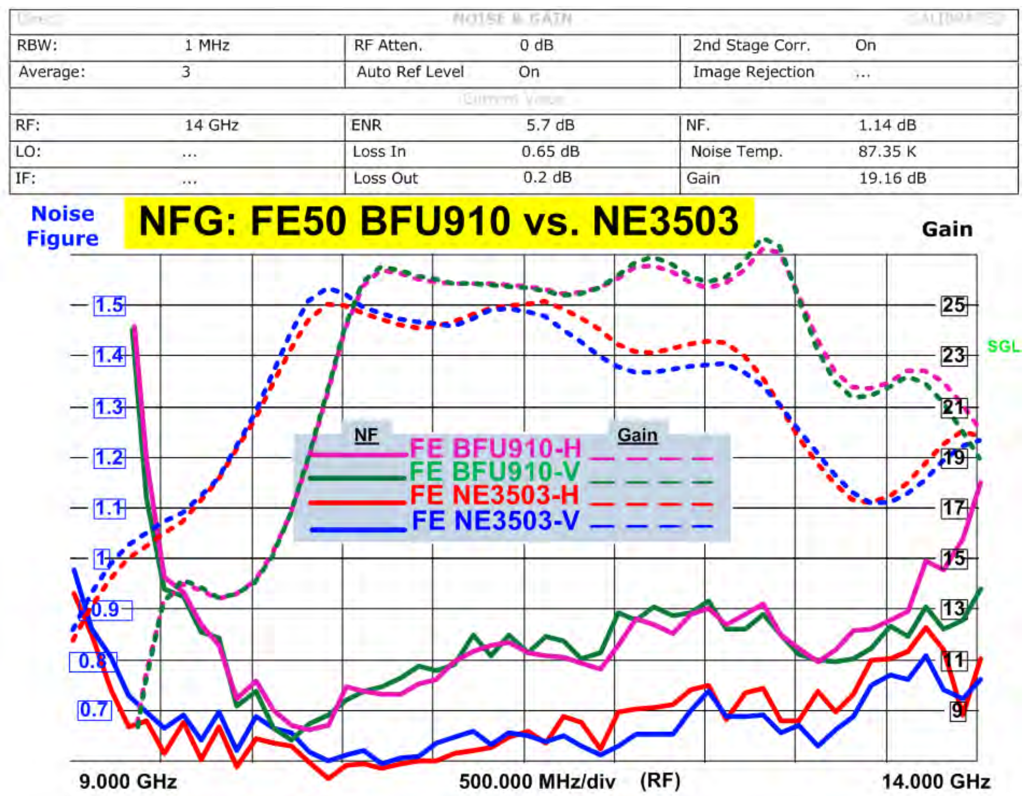
Table 2. Typical results measured on BFU910F FE Evaluation Board
Operating frequency is 10.7 ~12.75GHz unless otherwise specified; Temp = 25 ºC

Parameter	Symbol	Min	Typ	Max	Unit
Supply Voltage Vertical	V_{ccVer}	10	13	14	**V**
Supply Voltage Horizontal	V_{ccHor}	16	18	20	**V**
Supply Current	Icc	14.5	15.5	16.5	**mA**
Noise Figure	NF [1]		0.9	1.1	**dB**
Power Gain	G_p [2]	24.5	26		**dB**
Input Return Loss	RL_{in}	5	8		**dB**
Output Return Loss	RL_{out}	8	10		**dB**
Image rejection	IMR	15	20		**dB**
Cross Polar rejection	CPR	36	45		**dB**
Output third order intercept point	OIP3	10	12		**dBm**

[1] NF calibration uses Miteq AMF-3F as NF reference and Pre-Amp. Other professional amplifier can also be used.

[2] Gain calibration does not include the Input / Output losses.

6.2 NF and Gain (NFG)

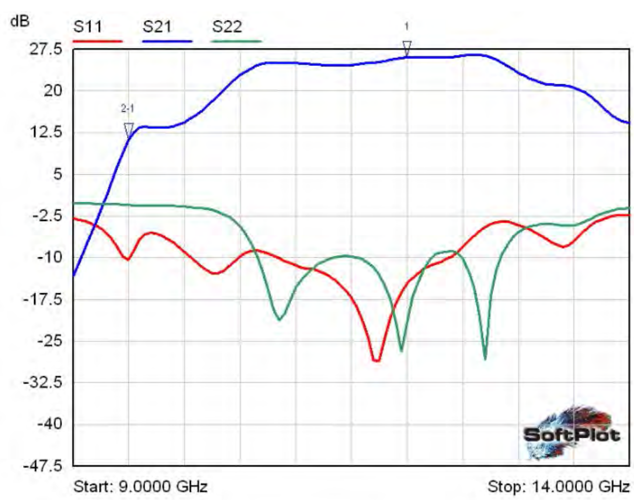


$NF_{FE\ BFU910F}$ = 0.85dB, $Gain_{FEBFU910F}$ = 26.5dB / $NF_{FE\ NE3503}$ = 0.65dB, $Gain_{FEBFU910F}$ = 23.5dB

Fig 13. NFG comparison for FE BFU910F vs FE NE3503

6.3 Gain, match and Image frequency rejection

Mkr	Trace	X-Axis	Value	Notes
1 ∇	S21	12.0000 GHz	25.72 dB	Ver ON
2-1 ∇	S21	-2.5000 GHz	-14.26 dB	Image rejection Ver IN

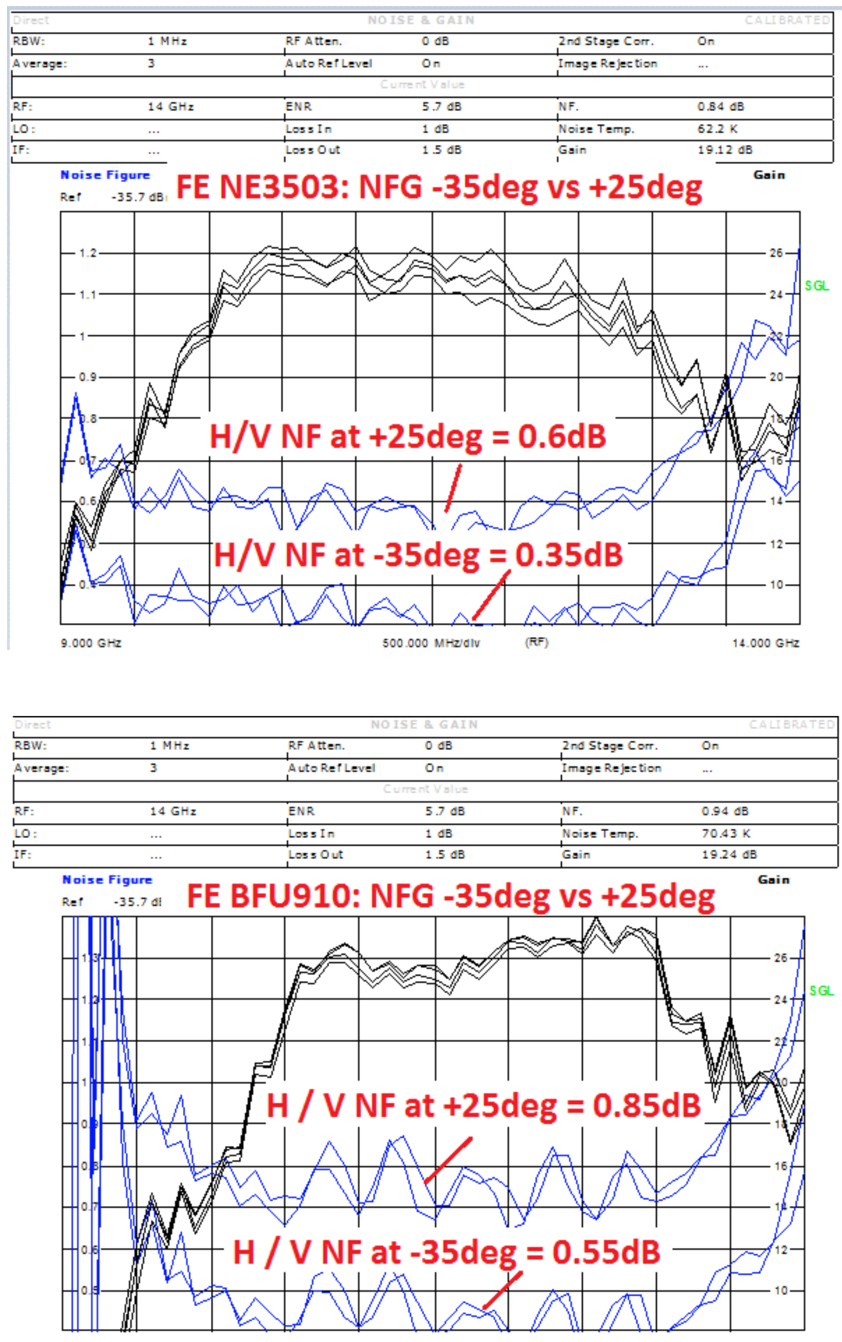


Mkr	Trace	X-Axis	Value	Notes
1 ∇	S21	12.0000 GHz	25.96 dB	Hor ON
2-1 ∇	S21	-2.5000 GHz	-14.85 dB	Image rejection Hor IN

Gain $_{FE\ BFU910F}$ = 26dB, RLIN >8dB, RLOUT > 10dB, IMR$_{FEBFU910F}$ > 15dB

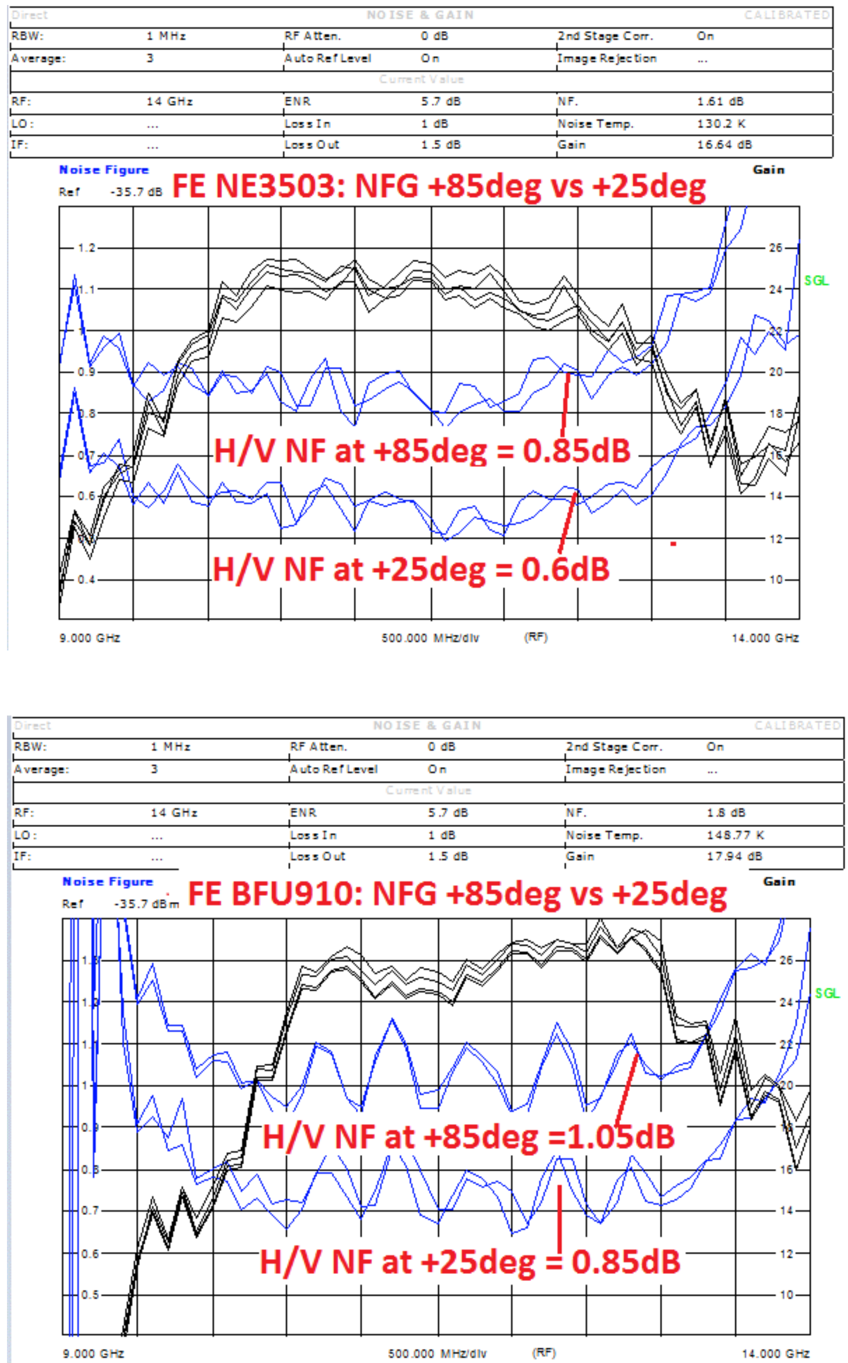
Fig 14. Gain match and Image rejection for FE BFU910F, Ver and Hor inputs

6.4 NF and gain variation with temperature



Similar NF variation (improvement) for BFU910F and NE3503

Fig 15. Low temperature behavior comparison for FE BFU910F vs. FE NE3503

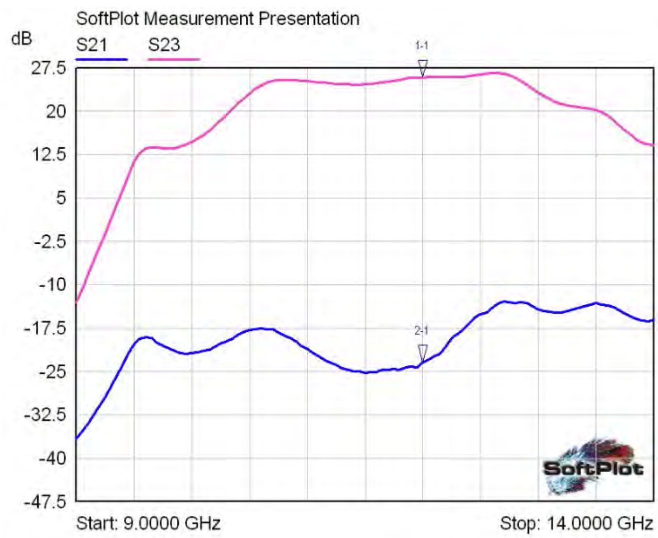


Similar NF variation (degradation) for BFU910F and NE3503

Fig 16. High temperature behavior comparison for FE BFU910F vs. FE NE3503

6.5 Cross polar rejection

Mkr	Trace	X-Axis	Value	Notes
1 ∇	S21	12.0000 GHz	25.75 dB	Ver ON
2-1 ∇	S23	12.0000 GHz	-51.84 dB	Cross polar Hor to Ver

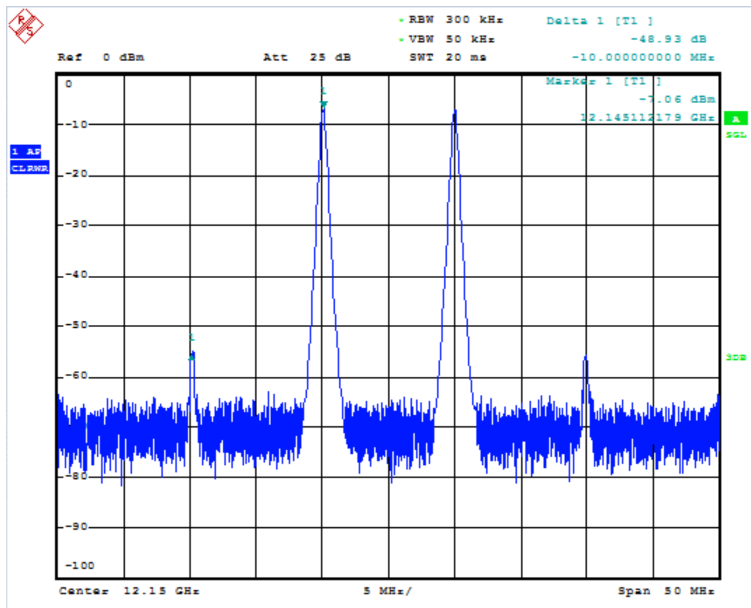


Mkr	Trace	X-Axis	Value	Notes
1-1 ∇	S23	12.0000 GHz	25.93 dB	Hor ON
2-1 ∇	S21	0 Hz	-49.45 dB	Cross Polar Ver to Hor

$Gain_{FE\ BFU910F} = 26dB$, $CPR_{FEBFU910F} = 45dB$

Fig 17. Cross polar rejection for FE BFU910F for Ver and Hor input

6.6 Linearity / OIP3



$OIP3 = P_{f1}+(P_{f1}-P_{2f1\_f2})/2$ = -7dBm + (-7 + 48)/2dB = 13.5dBm

IIP3 = OIP3 – Gain = 13.5dBm – 26dB = -12.5dBm

Fig 18. OIP3 for FE BFU910F

7. Equipment, setup and settings

Table 3 below summarizes the list of equipment per measurement type, used to check the performances for the BFU910F FE

Table 3. Equipment / measurement for BFU910F FE

Equipment, type & feature	Measurement					
	NFG	GMI	Xpol	OIP3	Temp	Current
FSU26: 26.5GHz SA with NF and PN option	1 x			1 x	1 x	
ZVA24: 24GHz 4 channel VNA		1 x	1x			
SMR20: 20GHz Signal Generator				2 x		
QL355TP: Dual Power Supply	1 x	1 x	1 x	1 x	1 x	1 x
HP346A: 5dB ENR Noise Source	1 x				1 x	
VT4002: Temperature chamber					1 x	

7.1 NF and gain (NFG)

Noise Figure and Gain - measurement settings			
Measurement	RF input at		FE bias / control
	Vertical	Horizontal	
NFG Ver	Noise Source	Open Load	Vcc= 13V
NFG Hor	Open Load	Noise Source	Vcc = 16V

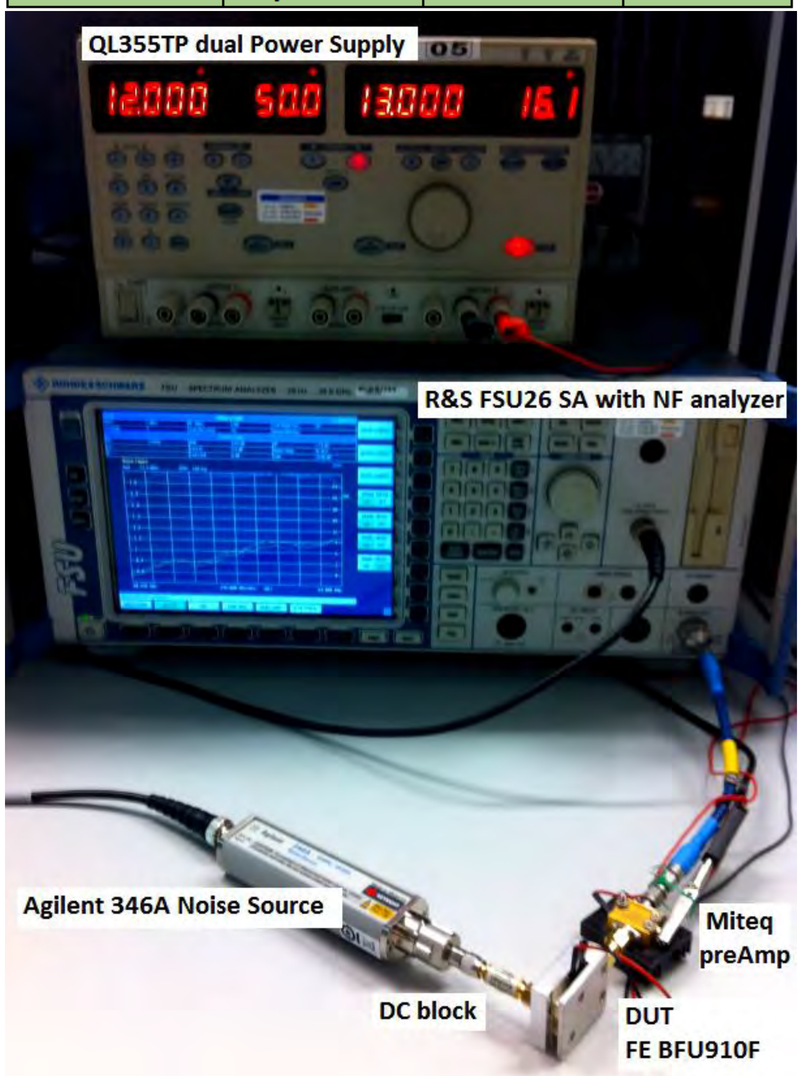


Fig 19. Noise Figure and Gain, measurement setup

7.2 Gain Match and Image rejection

Gain Match Image rejection - measurement settings			
Measurement	RF input at		FE bias / control
	Vertical	Horizontal	
GMI Ver	VNA port 1	Open Load	Vcc= 13V
GMI Hor	Open Load	VNA port 1	Vcc = 16V

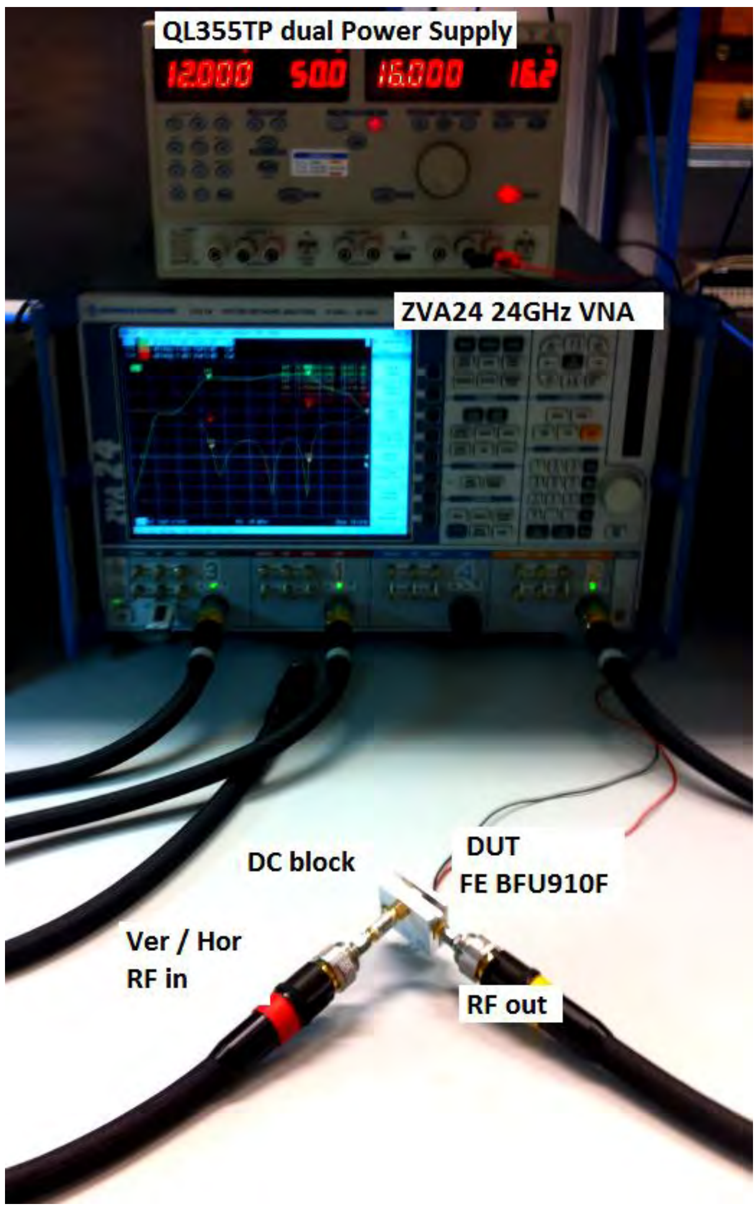


Fig 20. Gain Match and Image rejection, measurement setup

7.3 Cross polar rejection

Cross Polar rejection - measurement settings			
Measurement	RF input at		FE bias / control
	Vertical	Horizontal	
CPR Hor to Ver	VNA port 1	VNA port 3	Vcc= 13V
CPR Ver to Hor	VNA port 1	VNA port 3	Vcc = 16V

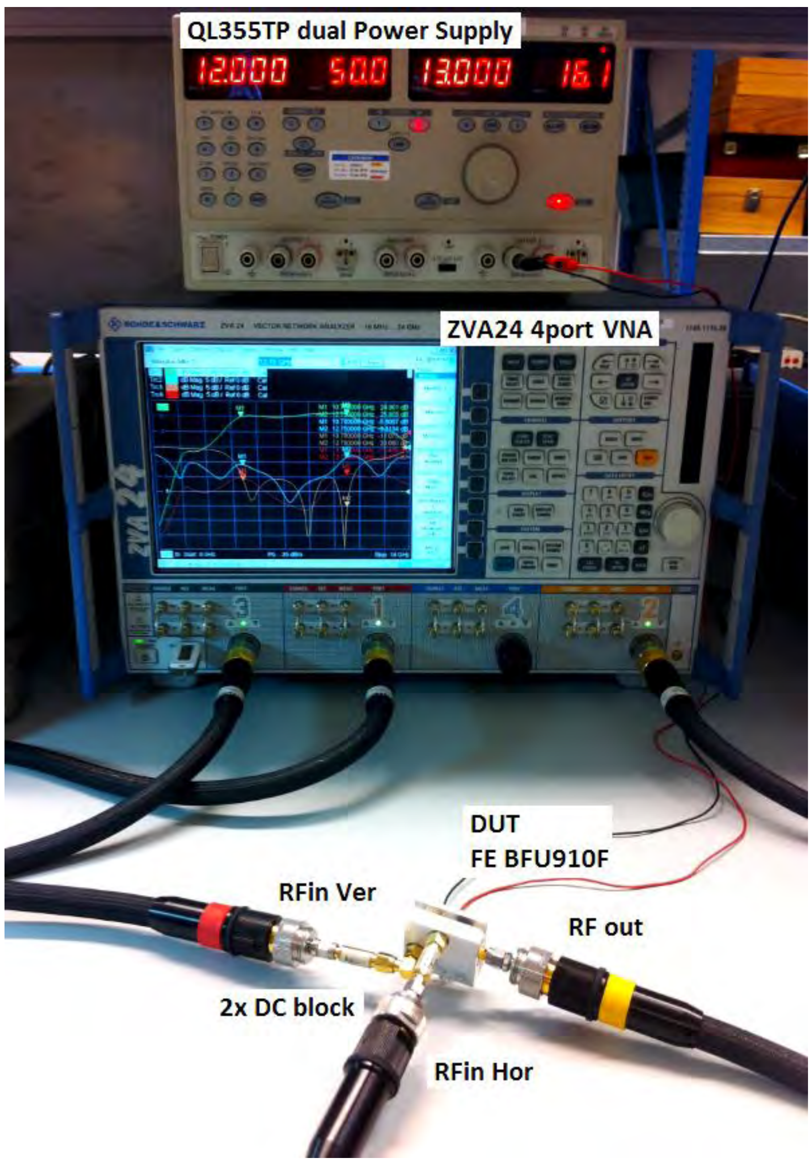


Fig 21. Cross polar rejection, measurement setup

7.4 Linearity / OIP3

OIP3 - measurement settings			
Measurement	Two tone 12.15GHz RF input at		FE bias / control
	Vertical	Horizontal	
OIP3 Ver ON	-35dBm	Open load	Vcc= 13V
OIP3 Hor ON	Open load	-35dBm	Vcc = 16V

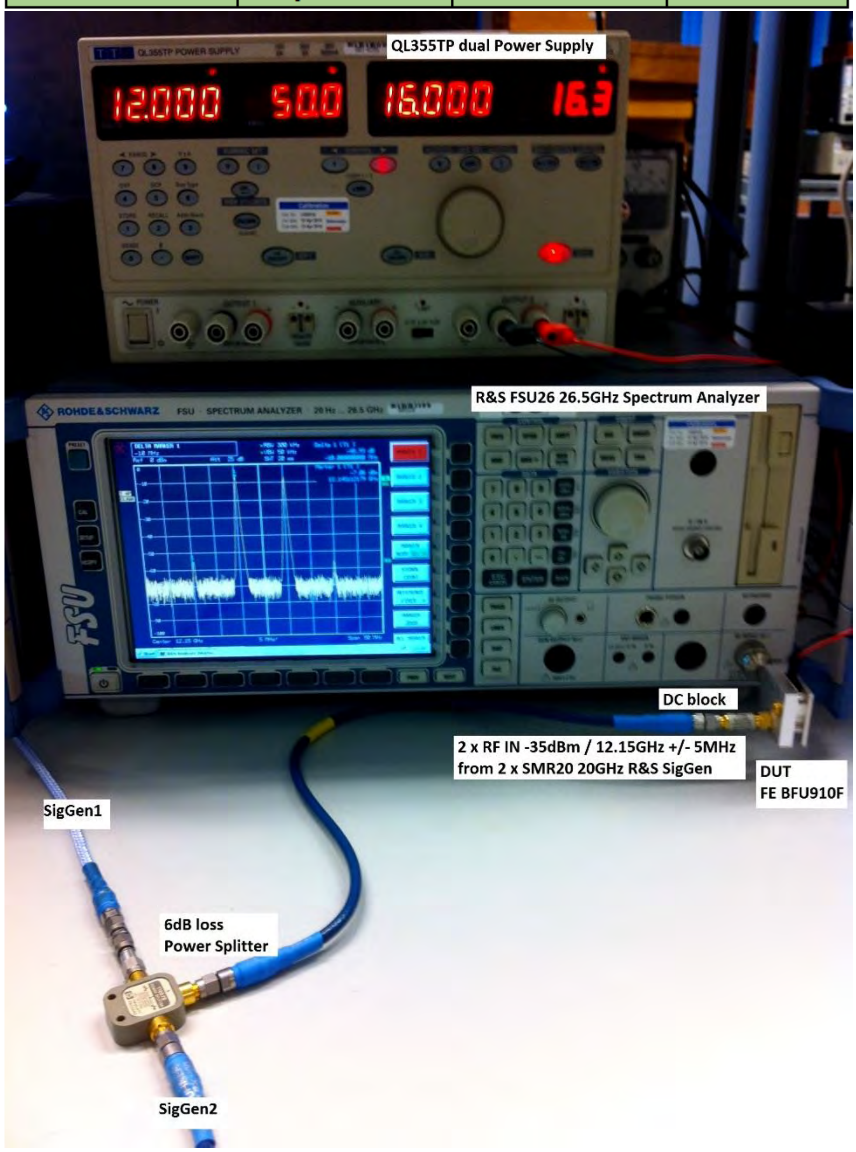


Fig 22. OIP3, measurement setup

8. Conclusions

- The Universal Single LNB FE solution based on BFU910F, proposed and analyzed in this document, meets all requirements from ASTRA standard
- The Universal Single LNB FE based on BFU910F, in comparison with NE3503 FE, has slightly worse NF performance. However, due to its higher gain, the noise figure degradation at overall LNB level is negligible.
- BFU910F in combination with LS9105 bias device, with its very good noise, high gain, low current, simplicity of the bias circuitry and small size, can provide a very competitive solution for Ku band LNB FE applications.

9. Abbreviations / explanations

Table 4. List of abbreviation within text

Abbreviation	Stands for
FE	Frontend
LNA	Low Noise Amplifier
LNB	Low Noise Block
DNC	Down Converter
HBT	Heterojunction Bipolar Transistor
SiGe	Silicon Germanium
SiGe-C	Silicon Germanium - Carbon
Ku band	LNB / FE in the frequency band of 10.7 ~12.75GHz
NF	Noise Figure
NFG	Noise Figure and gain
MW	Microwave (frequencies)
PN	Phase Noise
GMI	Gain, match and Image frequency rejection
CPR	Cross Polar rejection
SA	Spectrum Analyzer
VNA	Vector Network Analyzer
SigGen	Signal Generator
ENR	Excess Noise Ratio
RF	Radio frequency (block, frequency)
PCB	Printed Circuit Board
BOM	Bill of materials

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