Application Note No. 111

Low-cost, High-performance solution of BFP540ESD+SAW Filter for TPMS & RKE's Rx Front End

RF & Protection Devices

Never stop thinking

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Revision History: 2007-08-30, Rev. 1.2

Previous Version: 2006-12-14, Rev. 1.1

Page	Subjects (major changes since last revision)
All	Small changes in figure descriptions

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1 Low-cost, High-performance solution of BFP540ESD+SAW Filter for TPMS & RKE‘s Rx Front End

Overview

- The BFP540ESD of Infineon Technologies is an ESD-hardened SIEGET silicon transistor. The combination of high gain, low noise figure, excellent ESD performance makes the BFP540ESD ideal as a wide band feedback LNA to boost the sensitivity of Remote Keyless Entry (RKE) and Tire Pressure Monitoring Systems (TPMS).
- **Infineon BFP540ESD can stand 1000 V Electro-Static Discharge Pulses (Human Body Model) between any pair of terminals.**
- BCR400W is designed for stabilizing bias current from less than 0.2 mA to 200 mA even at low battery, which is applied to the evaluation board to improve DC reliability as RF performance is sensitive to current.
- Alternatives of the SAW filters B3710 B3711 made by EPCOS will be used after BFP540ESD LNA stage in the test board according to operation frequency. Measurement results of every stage and the whole board will be tested and shown.

Board overview

The Demo board as shown in Figure2 is built on low cost 1mm thickness FR4 PC-Board material of three layers, the cross-section of which is shown in Figure1. Schematic and bill of materials are shown in **Figure 3** and Table1 respectively.

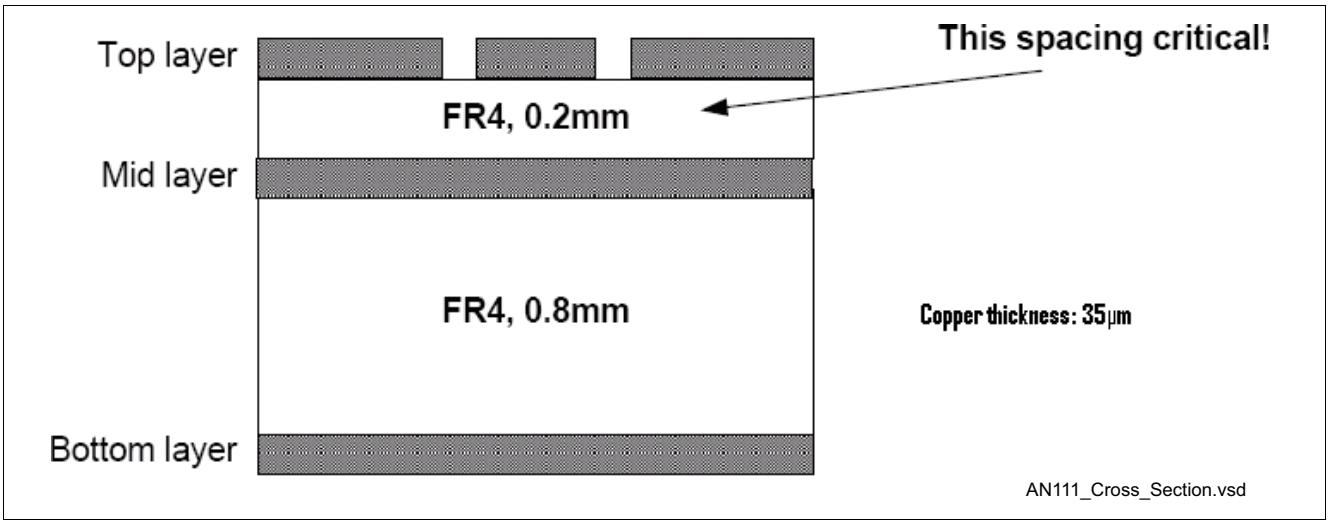

Figure 1 PCB Cross Section

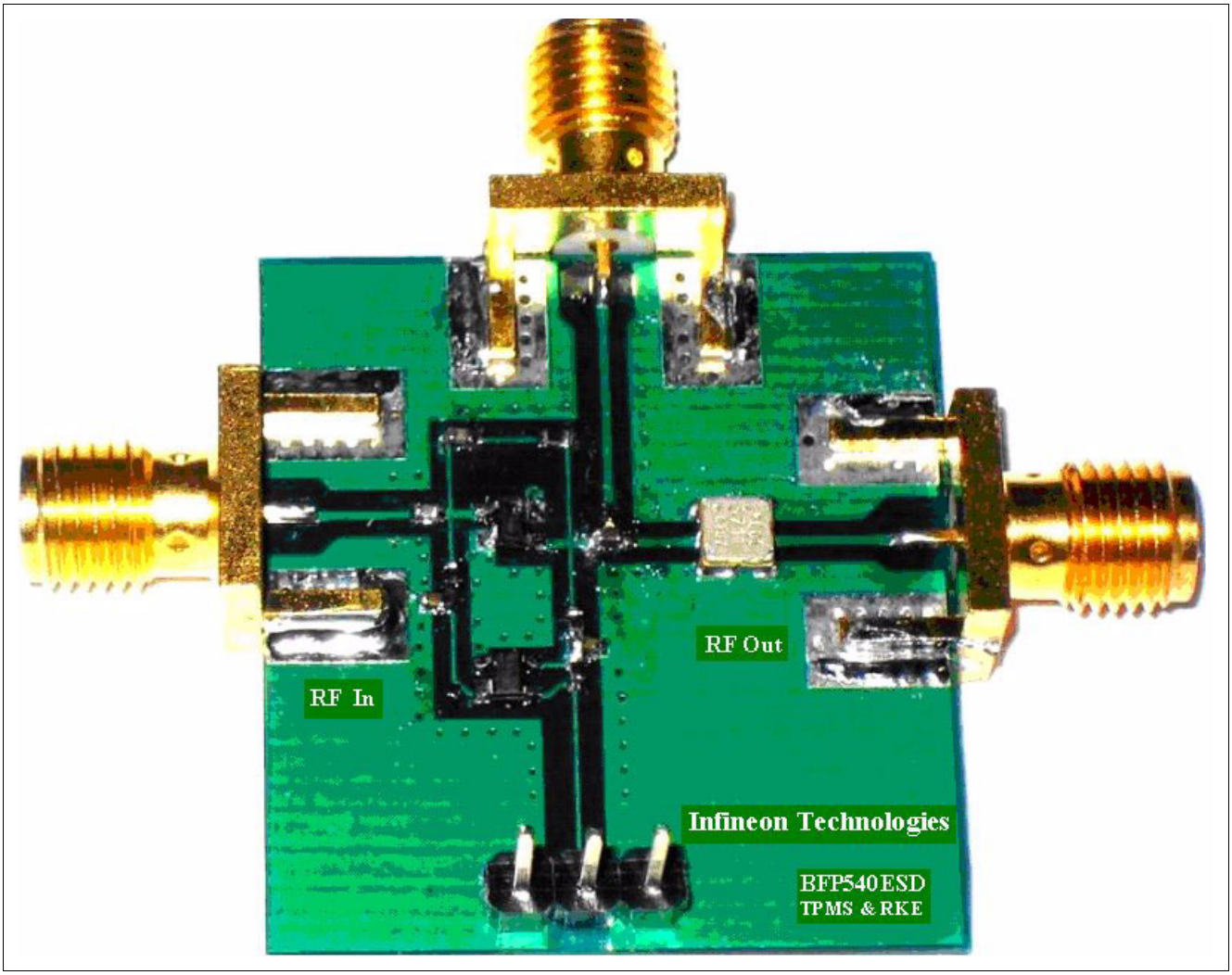

Figure 2 Photo of evaluation board

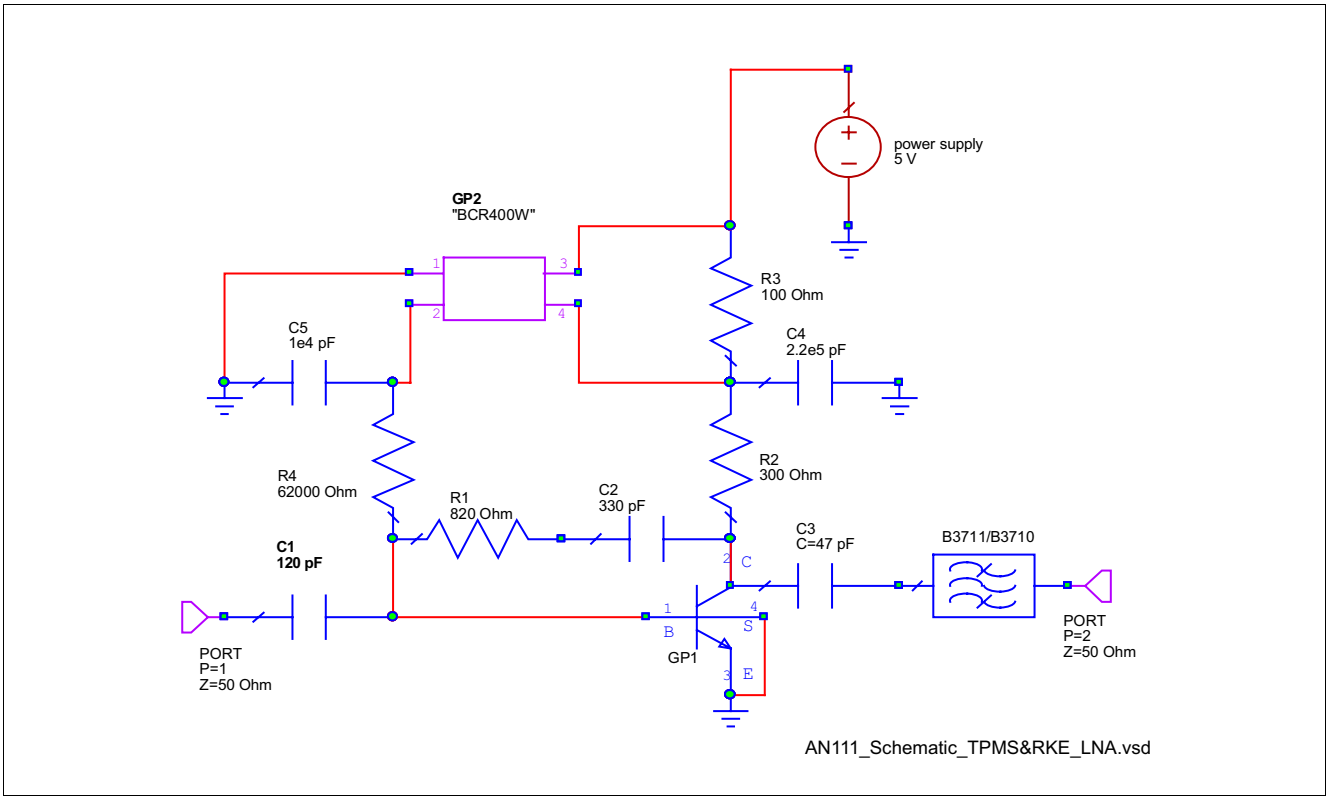

Figure 3 Schematic of TPMS&RKE LNA application

Table 1 Bill Of Material

Part Number	Value	Package	Manufacturer	Comment
C1	120 pF	0402	Various	DC Block, Input
C2	330 pF	0402	Various	DC Block for feedback network
C3	47 pF	0402	Various	DC Block
C4*	0.22 µF	0402	Various	Decoupling, Low Frequency
C5*	10000 pF	0402	Various	Decoupling
R1	750 Ω	0402	Various	Feedback Resistor for LNA
R2	300 Ω	0402	Various	Bias for Collector, Block AC Signal
R3	100 Ω	0402	Various	Bias for Collector, BCR400W Control Current by R3
R4	62 kΩ	0402	Various	Bias for Base
GP1	-	SOT343	Infineon Technologies	BFP540ESD ESD-Hardened to 1 kV HBM
GP2	-	SOT343	Infineon Technologies	BCR400W for stabilizing current
GP3	B3711/B3710	DCC6C	EPCOS	Band Pass SAW Filter

* In order to avoid loop oscillation (hunting), time constants must be chosen adequately, i.e. **C_1 >= 10 x C_2**

Table 2 Summary of BFP540ESD LNA Data

Parameter	Results	Comments
Frequency Range	0.3 MHz ~ 600 MHz	
DC Current	5 mA	
VCE of BFP540ESD	3 V	
Gain	17.9 dB @ 315 MHz 17.5 dB @ 434 MHz	
NF	1.47 dB @ 315 MHz 1.4 dB @ 434 MHz	
Input Return Loss	11.4 dB @ 315 MHz 11.1 dB @ 434 MHz	
Output Return Loss	12.6 dB @ 315 MHz 12.2 dB @ 434 MHz	
Reverse Isolation	-24 dB @ 315 MHz -24 dB @ 434 MHz	

Table 3 Summary of SAW Filter data

B3711		
Parameter	**Results**	**Comments**
Centre Frequency	315 MHz	
Insertion Loss	1.34 dB @ 315 MHz	
Input Return Loss	23.6 dB @ 315 MHz	
Output Return Loss	23.35 dB @ 315 MHz	
Attenuation	28.6 dB @ 310 MHz 29.7 dB @ 320 MHz 55.8 dB @ 440 MHz 70.8 dB @ 260 MHz	
B3710		
Parameter	**Results**	**Comments**
Centre Frequency	433.92 MHz	
Insertion Loss	2.0 dB @ 434 MHz	
Input Return Loss	24.8 dB @ 315 MHz	
Output Return Loss	20.5 dB @ 315 MHz	
Attenuation	22.6 dB @ 428 MHz 20.7 dB @ 440 MHz 68.5 dB @ 380 MHz 68.5 dB @ 470 MHz	

Table 4 Summary of the front end data (BFP540ESD LNA + Bandpass filter)

BFP540 + B3711		
Parameter	**Results**	**Comments**
Frequency Range	314.7 MHz ~ 315.3 MHz	
DC Current	5 mA	
V_{CE} of BFP540ESD	3 V	
Gain	16.5 dB @ 315 MHz	
NF	1.48 dB @ 315 MHz	
Input Return Loss	11.4 dB @ 315 MHz	
Output Return Loss	13.9 dB @ 315 MHz	
Reserve Isolation	25.1 dB @ 315 MHz	
Input 1dB compression	-21.17 dB @ 315 MHz	
Input IIP_3	-11.28 dBm	Two tones Tone1, -33 dB @ 314.5 MHz Tone2, -22 dB @ 315.5 MHz
BFP540 + B3710		
Parameter	**Results**	**Comments**
Frequency Range	433 MHz ~ 434.71 MHz	
DC Current	5 mA	
V_{CE} of BFP540ESD	3 V	
Gain	15.93 dB @ 434 MHz	
NF	1.42 dB @ 434 MHz	
Input Return Loss	11.37 dB @ 434 MHz	
Output Return Loss	13.52 dB @ 434 MHz	
Reserve Isolation	-25.7 dB @ 434 MHz	
Input 1dB compression	-15.06 dB @ 434 MHz	
Input IIP_3	-10.96 dBm	Two tones Tone1, -33 dB @ 433.5 MHz Tone2, -22 dB @ 434.5 MHz

K and B1 of BFP540ESD LNA

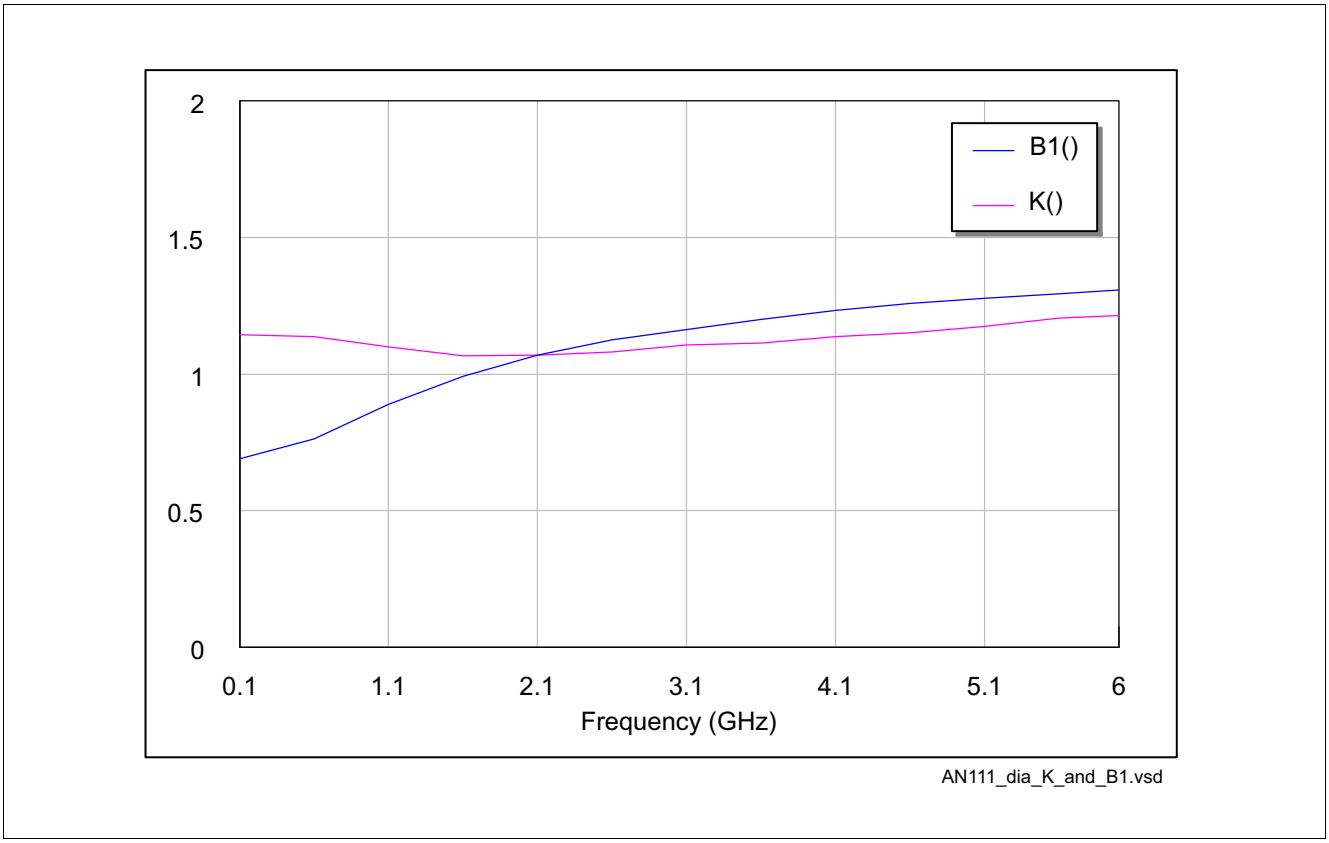

Figure 4 K(f) and B1(f)

Table 5 Noise Figure of BFP540ESD LNA Alone! (429 MHz ~ 439 MHz)

Frequency	Noise Figure	Gain
429.00000 MHz	1.4535 dB	16.8217 dB
430.00000 MHz	1.4239 dB	16.8102 dB
431.00000 MHz	1.3928 dB	16.8081 dB
432.00000 MHz	1.4028 dB	16.7978 dB
433.00000 MHz	1.3976 dB	16.7917 dB
434.00000 MHz	1.3975 dB	16.7948 dB
435.00000 MHz	1.4072 dB	16.7872 dB
436.00000 MHz	1.3978 dB	16.8054 dB
437.00000 MHz	1.3953 dB	16.8091 dB
438.00000 MHz	1.3975 dB	16.8161 dB
439.00000 MHz	1.4203 dB	16.8087 dB

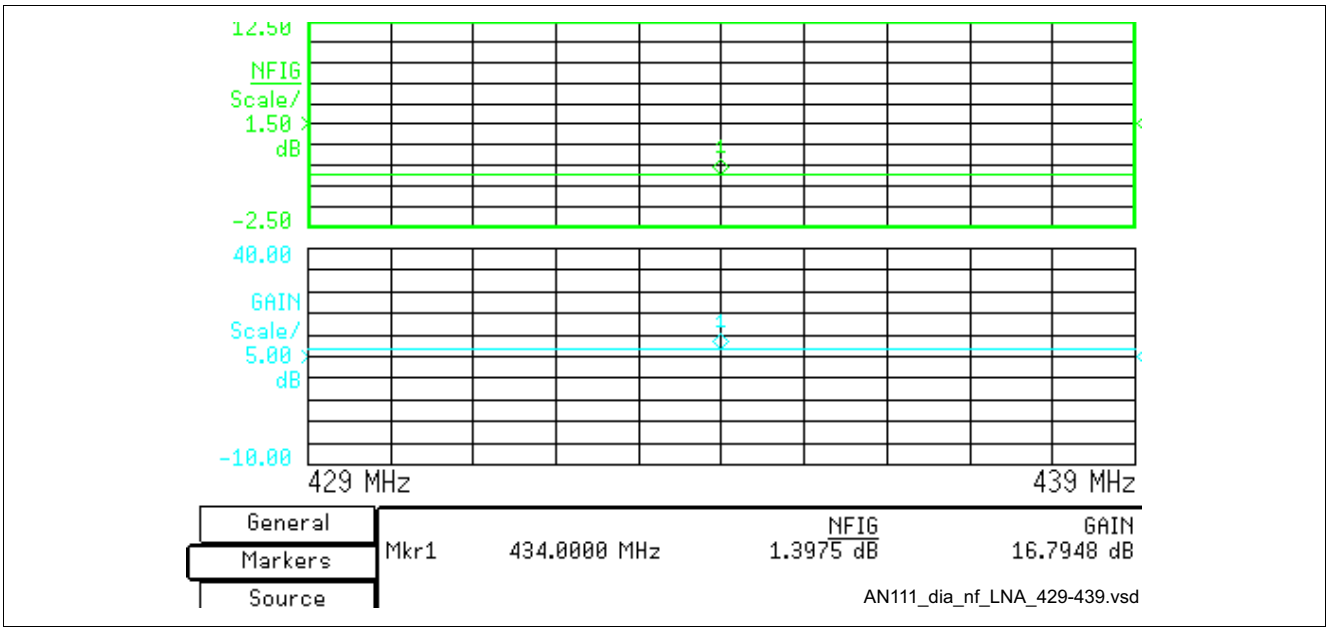

Figure 5 Noise Figure of BFP540ESD LNA Alone! (429 MHz ~ 439 MHz)

Table 6 Noise Figure of BFP540ESD LNA Alone! (310 MHz ~ 320 MHz)

Frequency	Noise Figure	Gain
310.00000 MHz	1.4276 dB	17.5669 dB
311.00000 MHz	1.4417 dB	17.5742 dB
312.00000 MHz	1.4781 dB	17.5883 dB
313.00000 MHz	1.4844 dB	17.6047 dB
314.00000 MHz	1.4832 dB	17.6190 dB
315.00000 MHz	1.4701 dB	17.6160 dB
316.00000 MHz	1.4714 dB	17.6143 dB
317.00000 MHz	1.4423 dB	17.6207 dB
318.00000 MHz	1.4510 dB	17.6100 dB
319.00000 MHz	1.4497 dB	17.6053 dB
320.00000 MHz	1.4667 dB	17.6062 dB

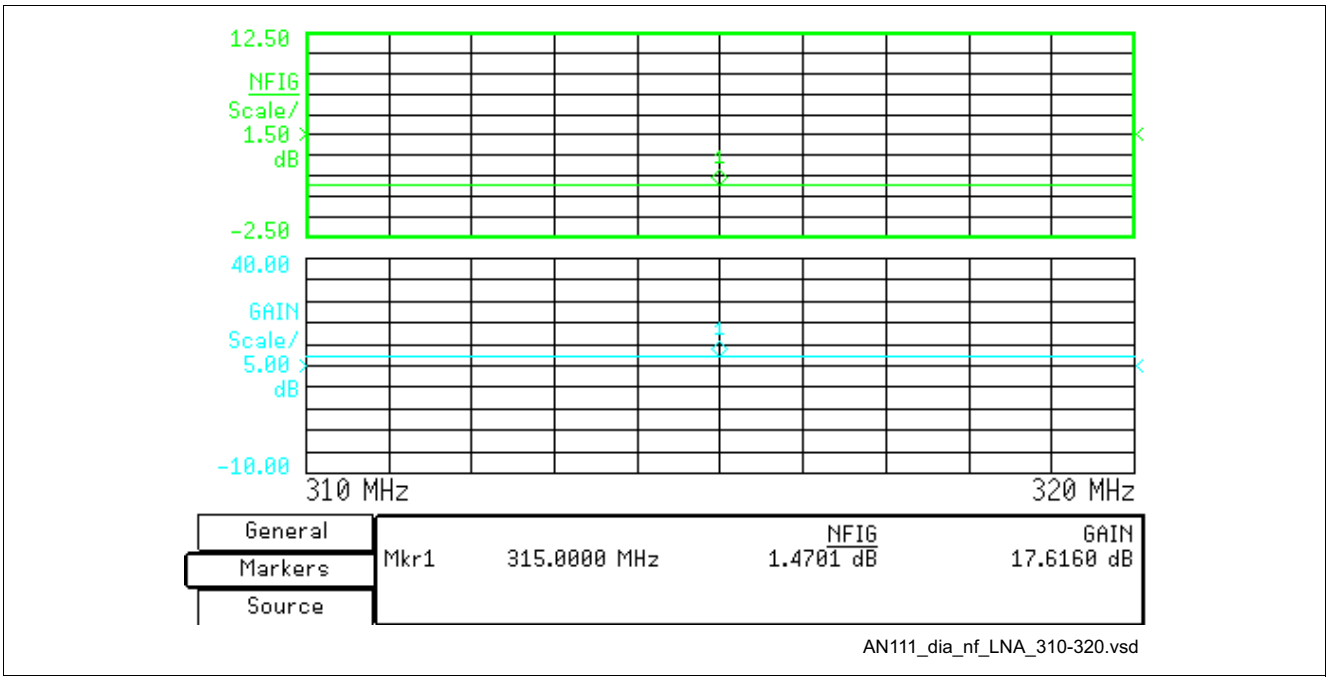

Figure 6 Noise Figure of BFP540ESD LNA Alone! (310 MHZ ~ 320 MHz)

Table 7 Noise Figure of Front End (BFP540ESD LNA Plus SAW Filter B3710)

Frequency	Noise Figure	Gain
429.00000 MHz	1.9124 dB	09.3424 dB
430.00000 MHz	1.4987 dB	12.5603 dB
431.00000 MHz	1.4629 dB	14.3943 dB
432.00000 MHz	1.4232 dB	15.3753 dB
433.00000 MHz	1.4064 dB	15.8708 dB
434.00000 MHz	1.4205 dB	15.9757 dB
435.00000 MHz	1.4197 dB	15.8990 dB
436.00000 MHz	1.4267 dB	15.5684 dB
437.00000 MHz	1.4484 dB	14.7000 dB
438.00000 MHz	1.5412 dB	12.8730 dB
439.00000 MHz	1.6300 dB	09.9760 dB

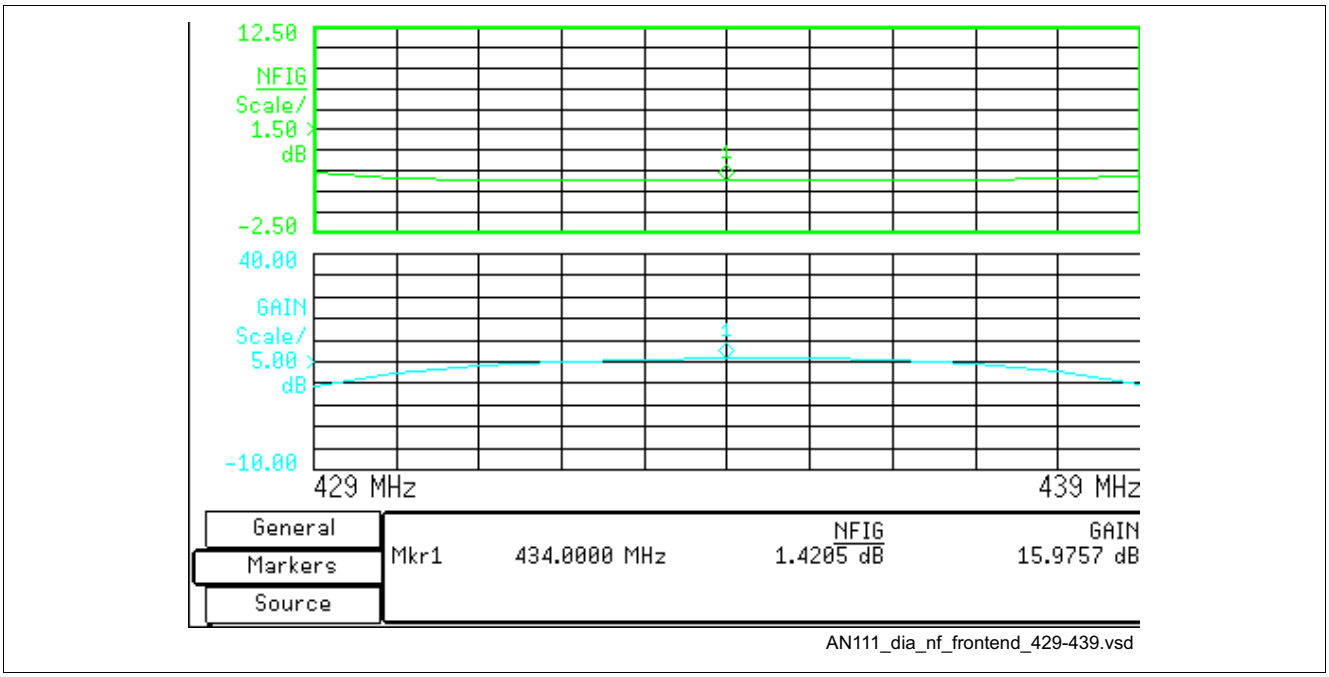

Figure 7 Noise Figure of Front End (BFP540ESD LNA Plus SAW Filter B3710)

Table 8 Noise Figure of Front End (BFP540ESD LNA Plus SAW Filter B3711)

Frequency	Noise Figure	Gain
310.00000 MHz	2.2143 dB	00.3415 dB
311.00000 MHz	1.6532 dB	06.7412 dB
312.00000 MHz	1.5981 dB	11.4291 dB
313.00000 MHz	1.5628 dB	14.2293 dB
314.00000 MHz	1.5060 dB	15.6274 dB
315.00000 MHz	1.4844 dB	16.0749 dB
316.00000 MHz	1.4775 dB	15.8385 dB
317.00000 MHz	1.5128 dB	14.7086 dB
318.00000 MHz	1.5952 dB	12.3993 dB
319.00000 MHz	1.7307 dB	08.9415 dB
320.00000 MHz	1.9356 dB	04.6864 dB

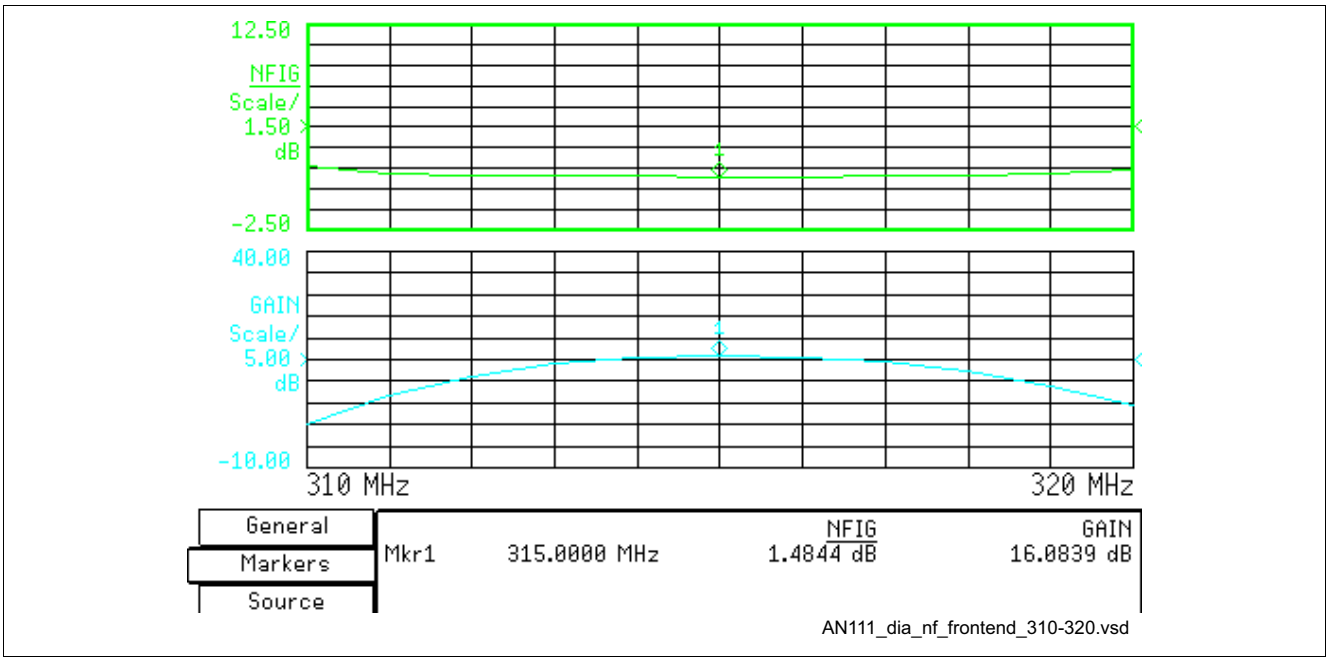

Figure 8 Noise Figure of Front End (BFP540ESD LNA Plus SAW Filter B3711)

Return Loss of BFP540ESD LNA Alone!

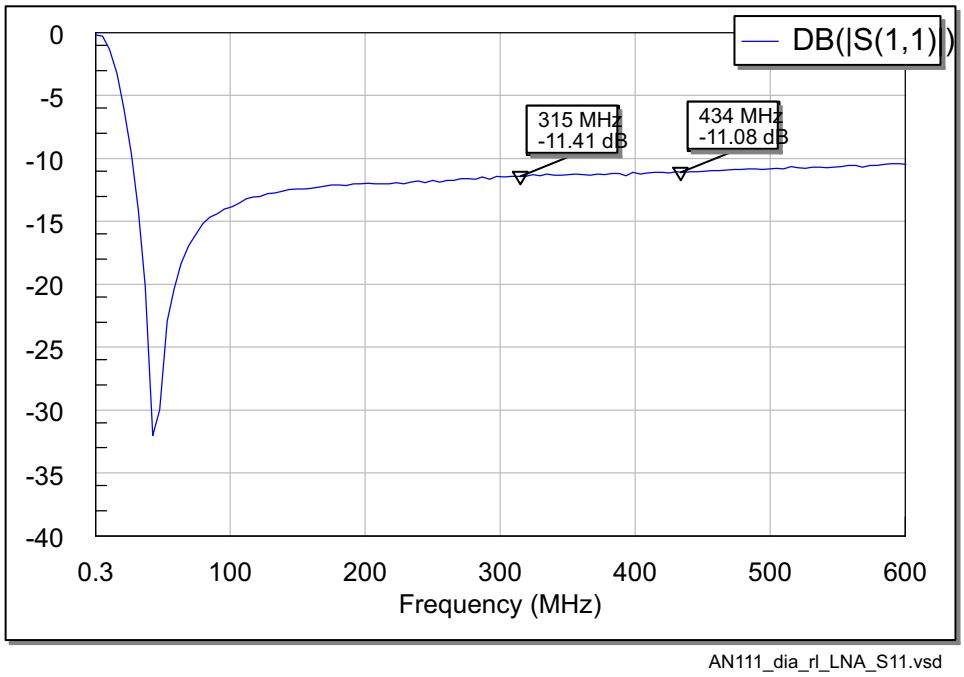

Figure 9 $S_{11}(f)$

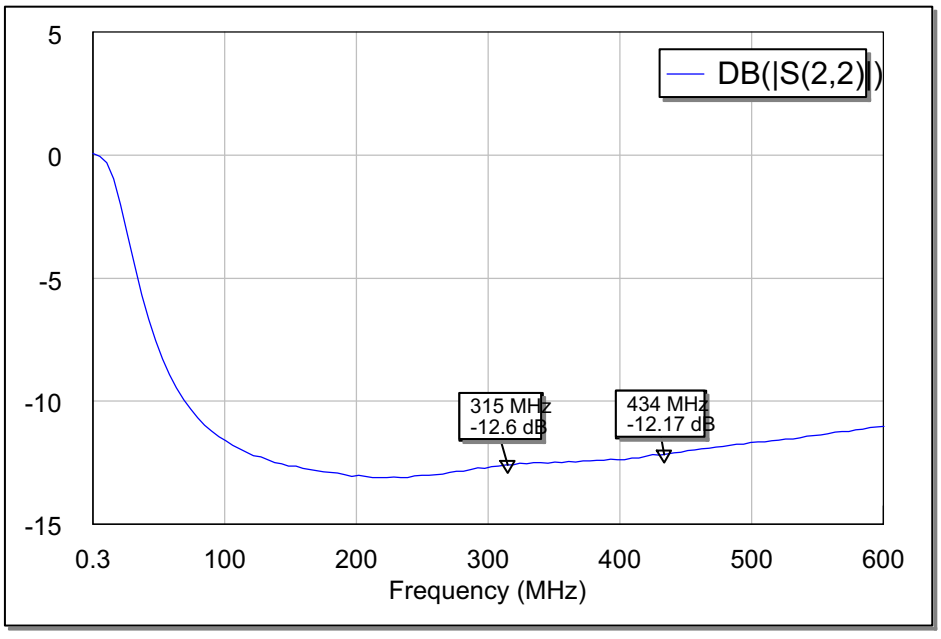

Figure 10 $S_{22}(f)$

Forward Gain and Isolation of BFP540 LNA Alone!

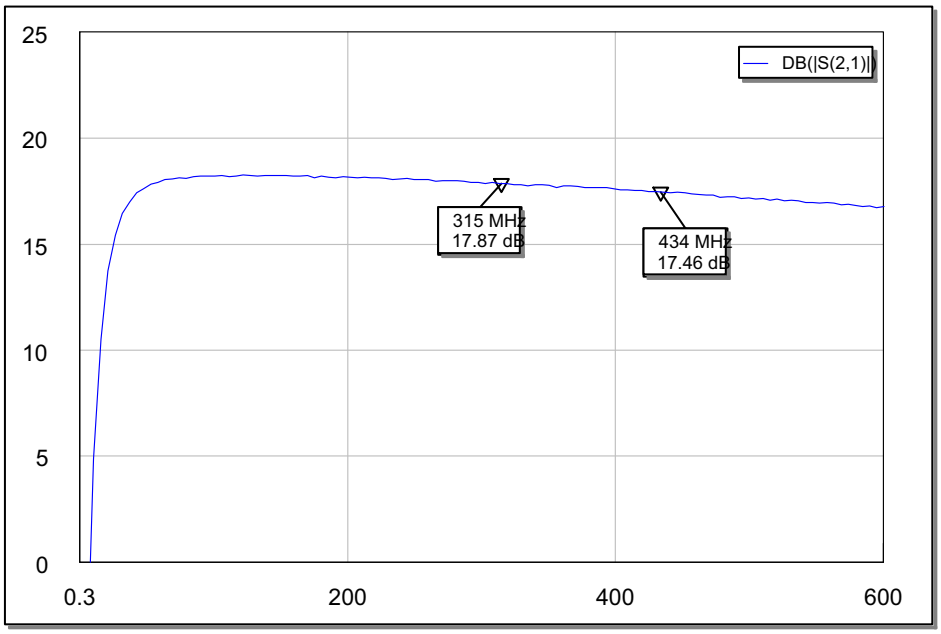

Figure 11 $S_{21}(f)$

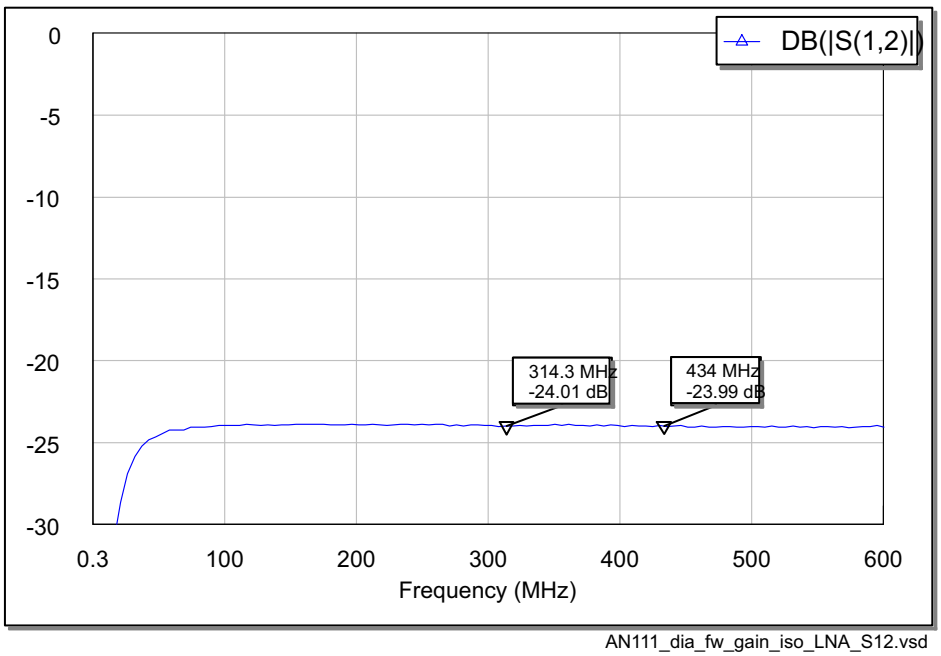

Figure 12 $S_{12}(f)$

Return Loss of Front End (BFP540ESD LNA Plus SAW Filter B3710)

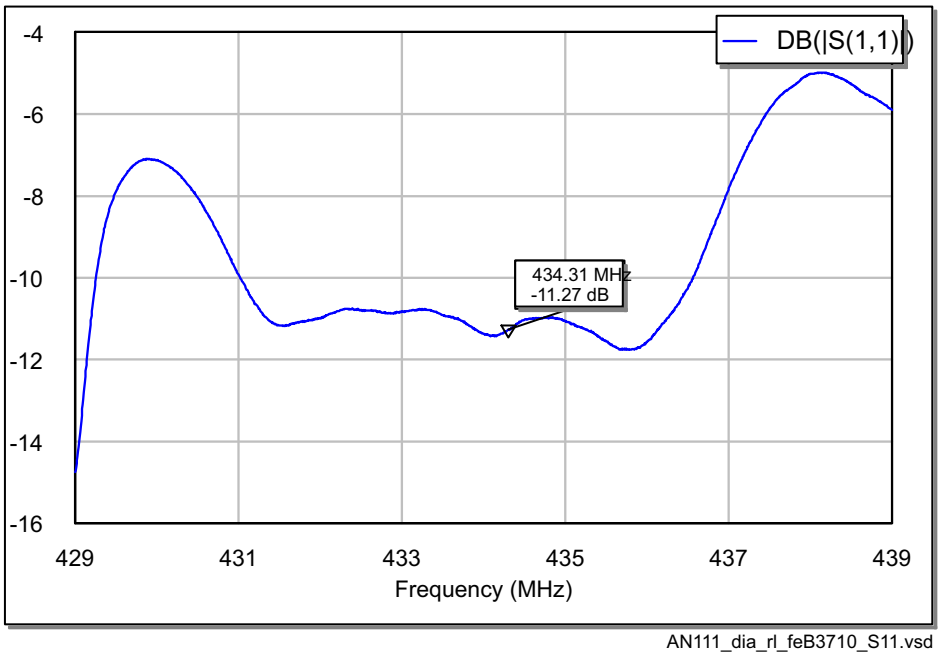

Figure 13 $S_{11}(f)$

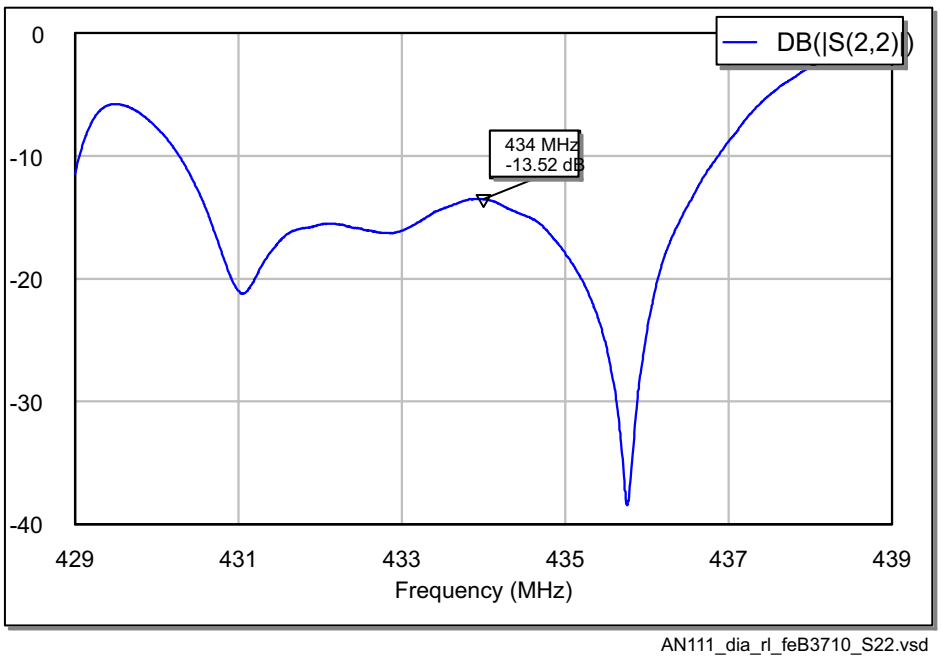

Figure 14 $S_{22}(f)$

Smith Chart of Return Loss (BFP540ESD LNA Plus SAW Filter B3710)

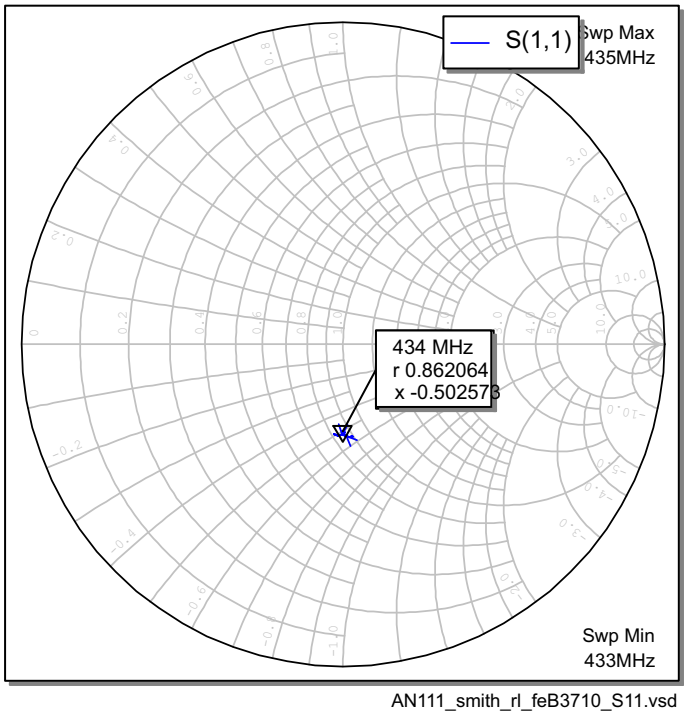

Figure 15 $S_{11}(f)$

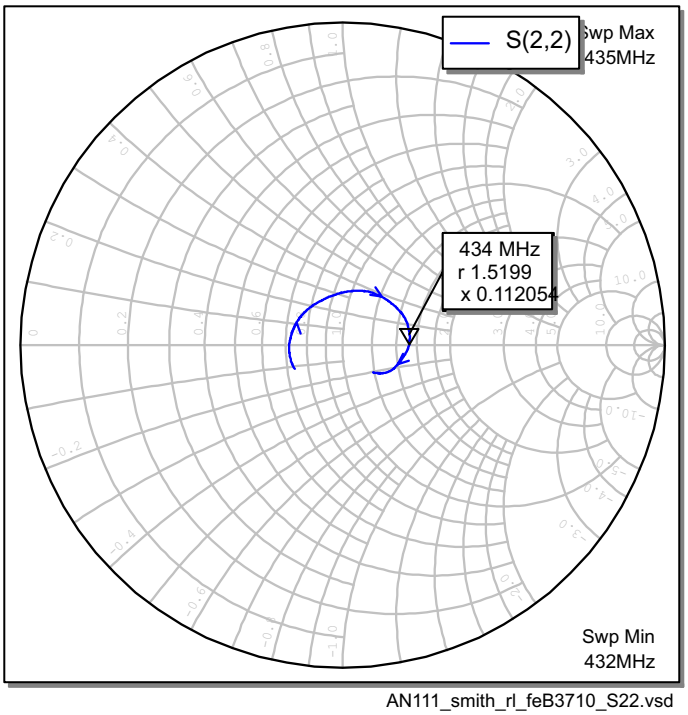

Figure 16 $S_{22}(f)$

Forward Gain and Isolation of Front End (BFP540ESD LNA Plus SAW Filter B3710)

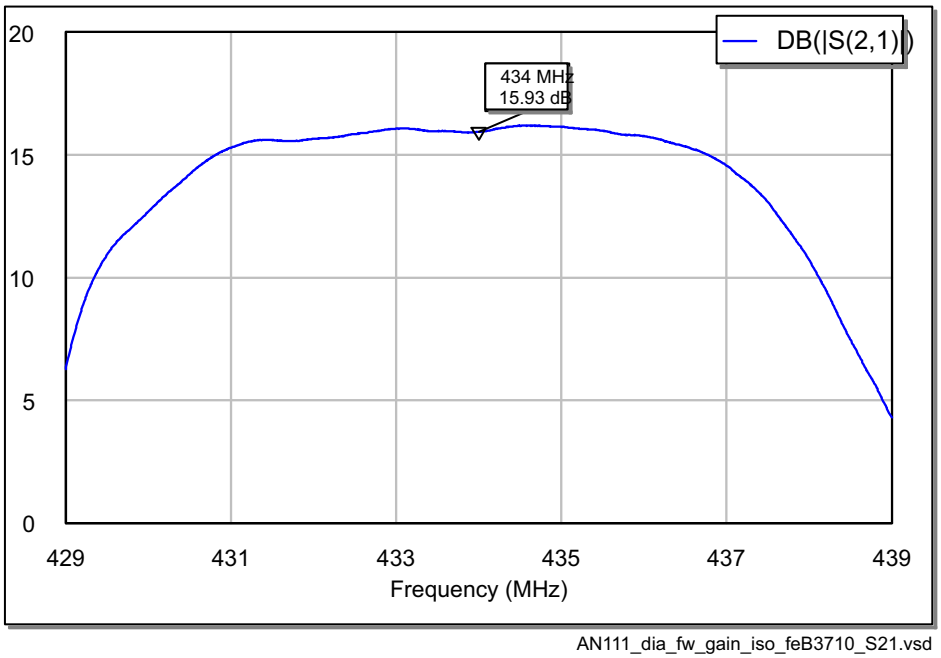

Figure 17 $S_{21}(f)$

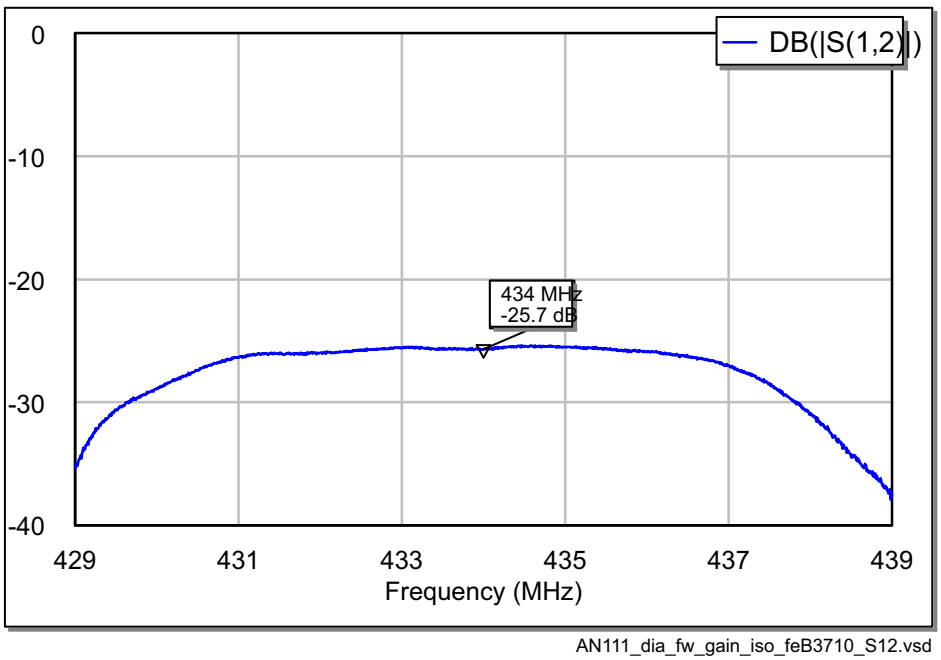

Figure 18 $S_{12}(f)$

Input IIP3 of Front End (BFP540ESD Plus SAW Filter B3710)

Two Tones:

- Tone1, -33 dB @ 433.5 MHz
- Tone2, -33 dB @ 434.5 MHz

Input IP_3 = -33+(44.08/2) = -10.96 dBm

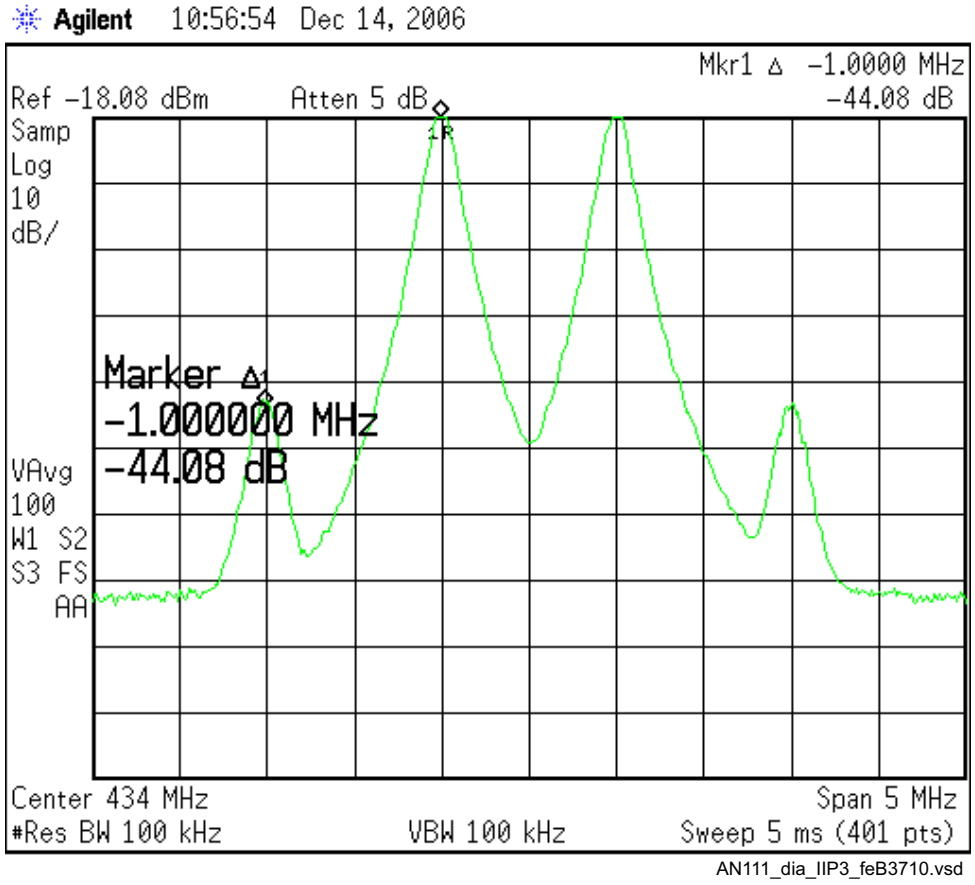

Figure 19 Input IIP_3 of Front End (BFP540ESD Plus SAW Filter B3710)

Input 1dB compression of Front End (BFP540ESD Plus SAW Filter B3710')

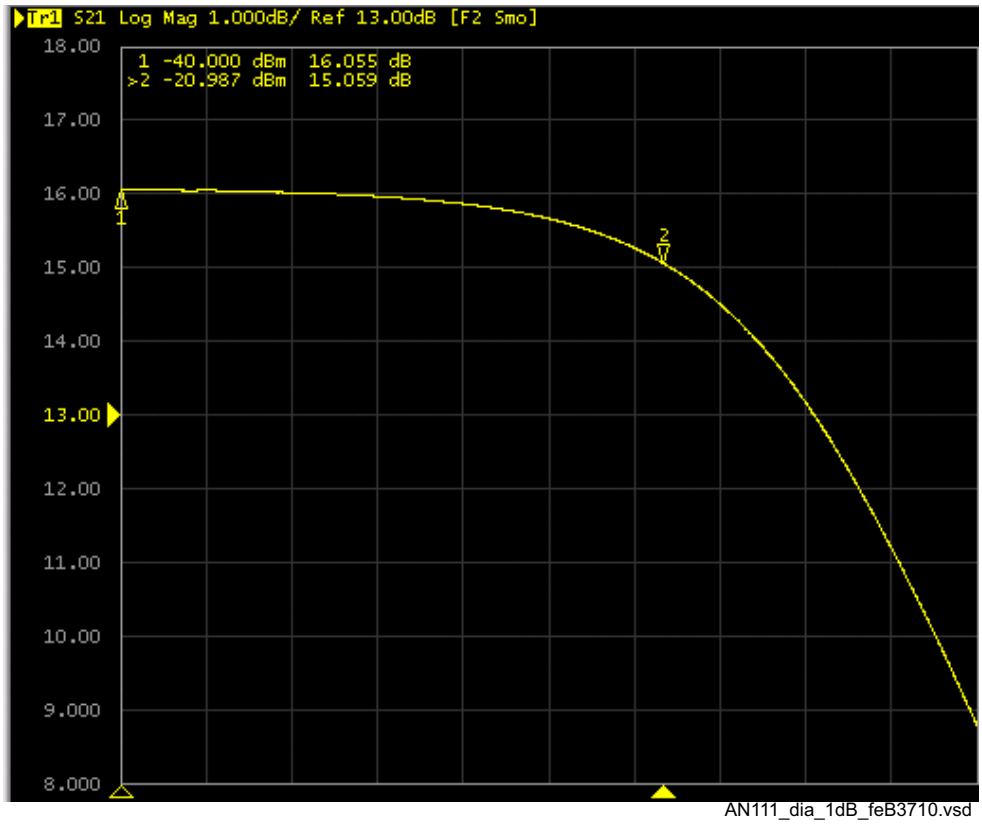

Figure 20 Input 1dB compression of Front End (BFP540Esd Plus SAW Filter B3710)

Return Loss of Front End (BFP540ESD LNA Plus SAW Filter B3711)

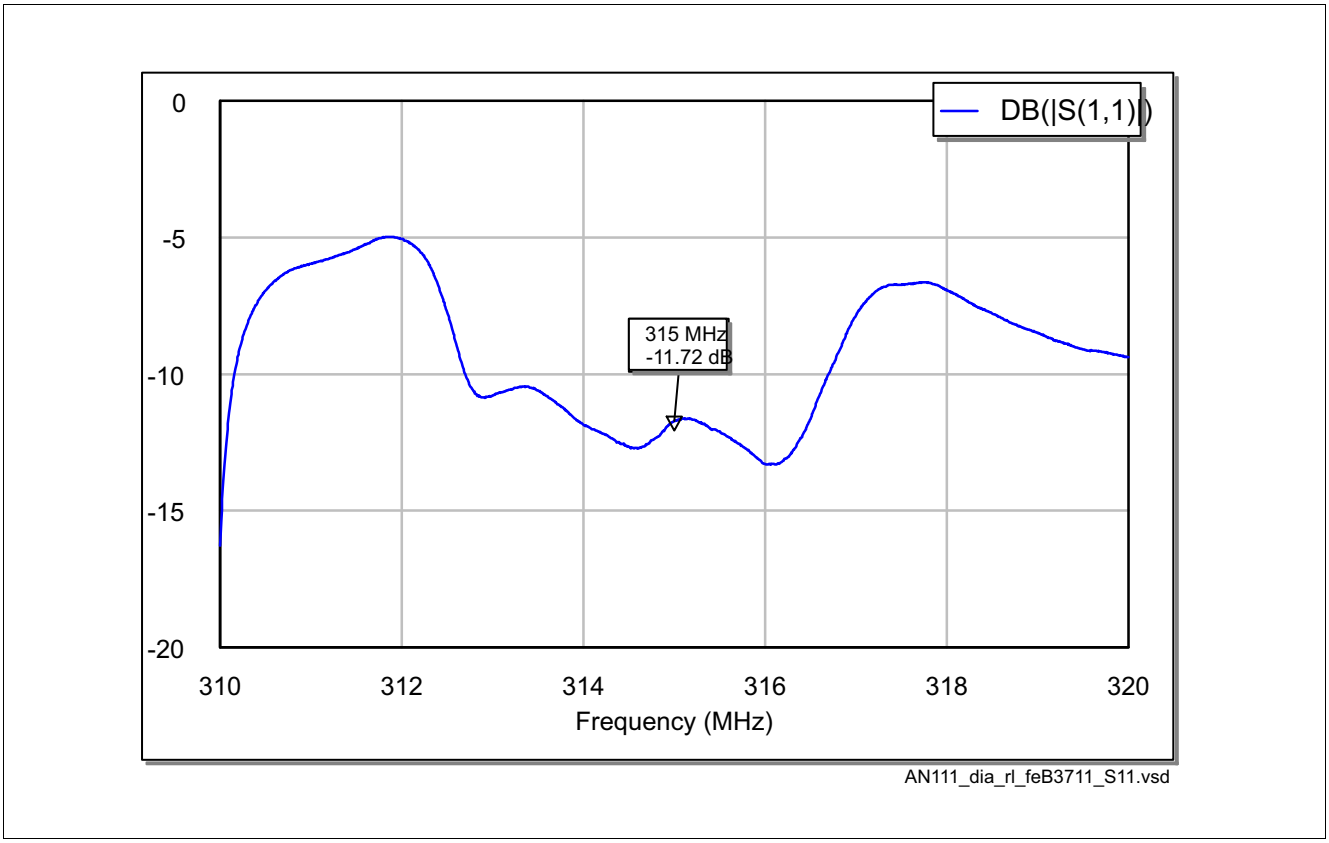

Figure 21 $S_{11}(f)$

Smith Chart of Return Loss of Front End (BFP540ESD LNA Plus SAW Filter B3711)

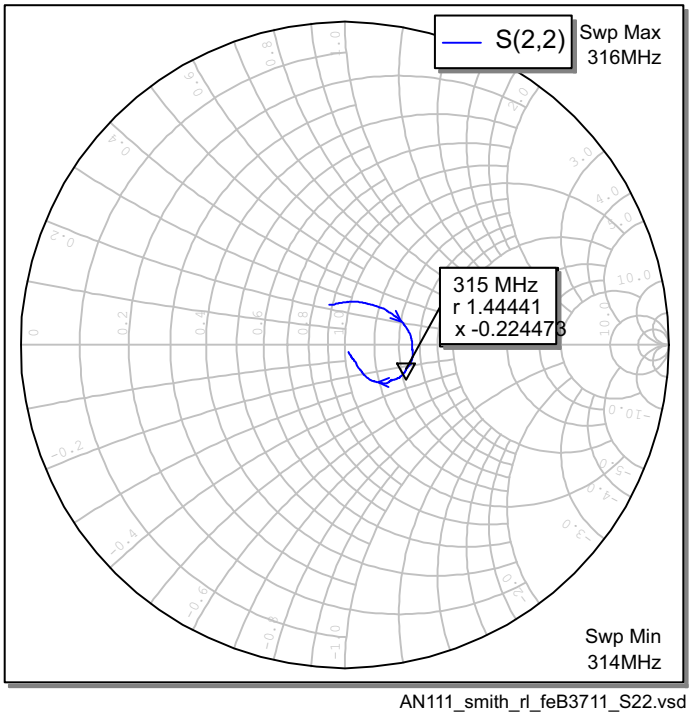

Figure 22 $S_{22}(f)$

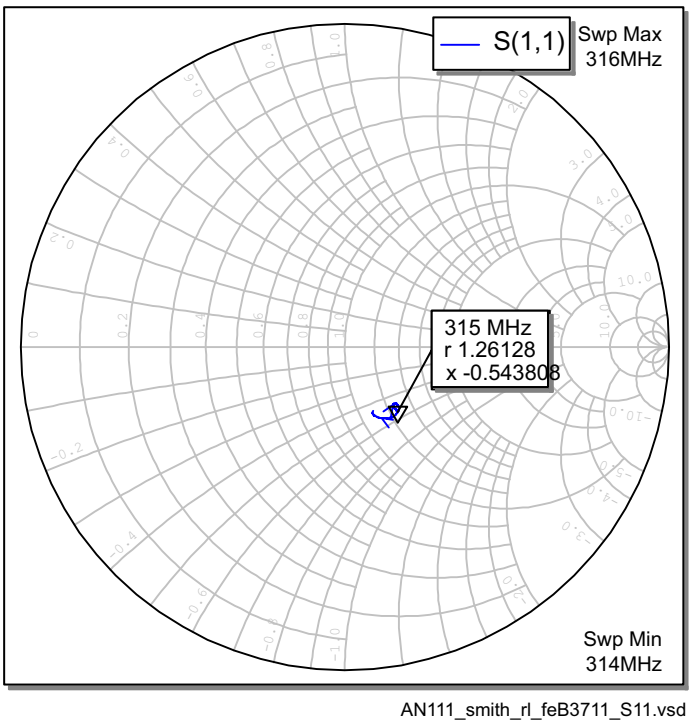

Figure 23 $S_{11}(f)$

Forward Gain and Isolation of Front End (BFP540ESD LNA Plus SAW Filter B3711)

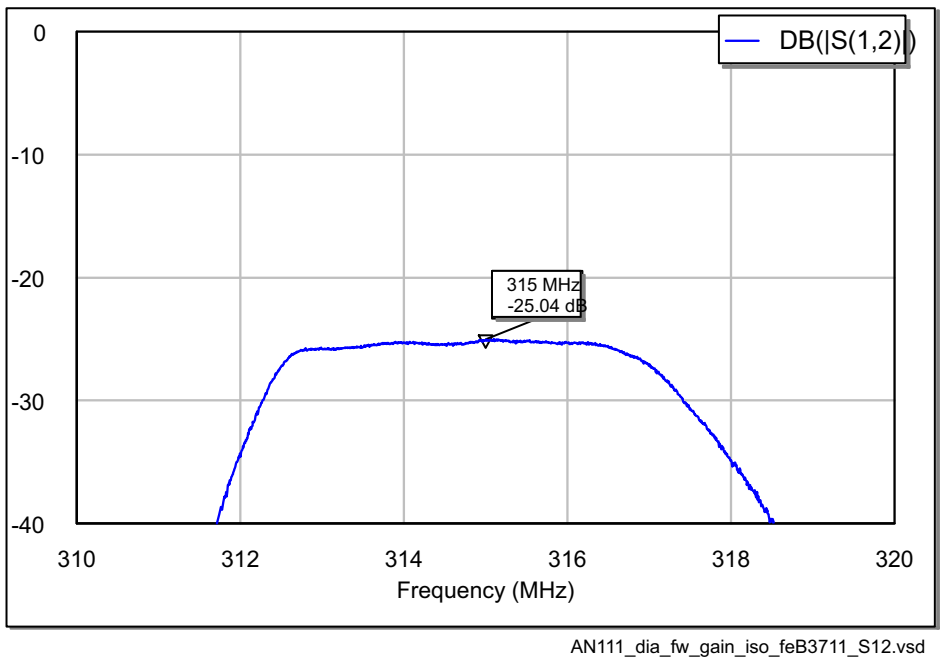

Figure 24 $S_{12}(f)$

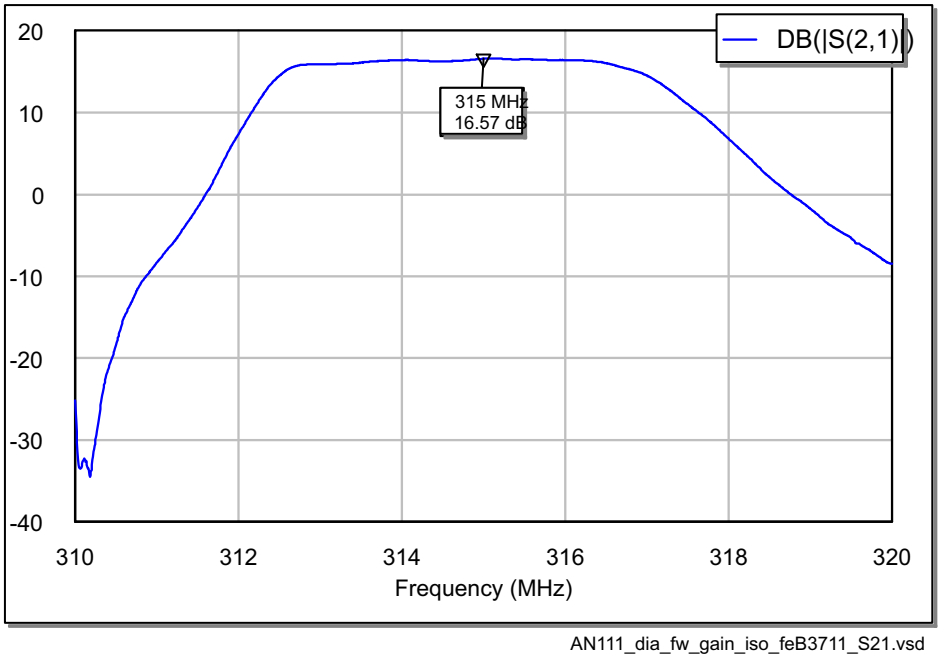

Figure 25 $S_{21}(f)$

Input IIP3 of Front End (BFP540ESD Plus SAW Filter B3711)

Two Tones:

- Tone1, -33 dB @ 314.5 MHz
- Tone2, -33 dB @ 315.5 MHz

Input IP_3 = -33+(43.43/2) = -11.28 dBm

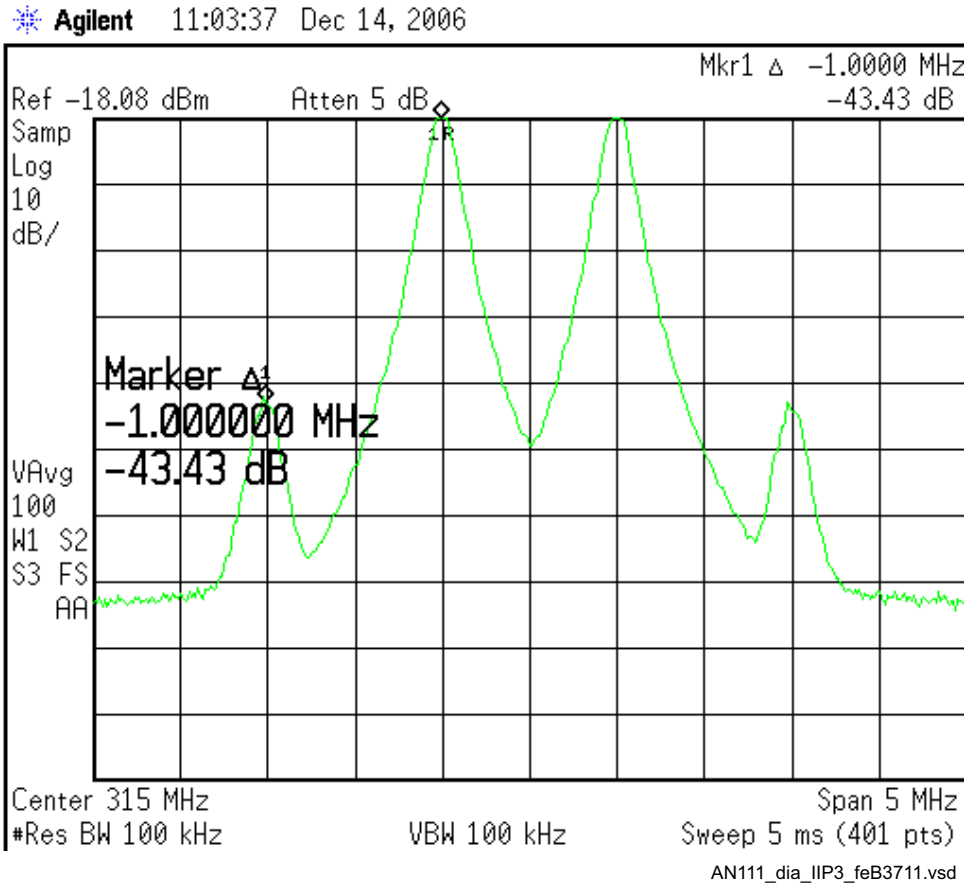

Figure 26 Input IIP_3 of Front End (BFP540ESD Plus SAW Filter B3711)

Input 1 dB compression of Front End (BFP540ESD Plus SAW Filter B3711')

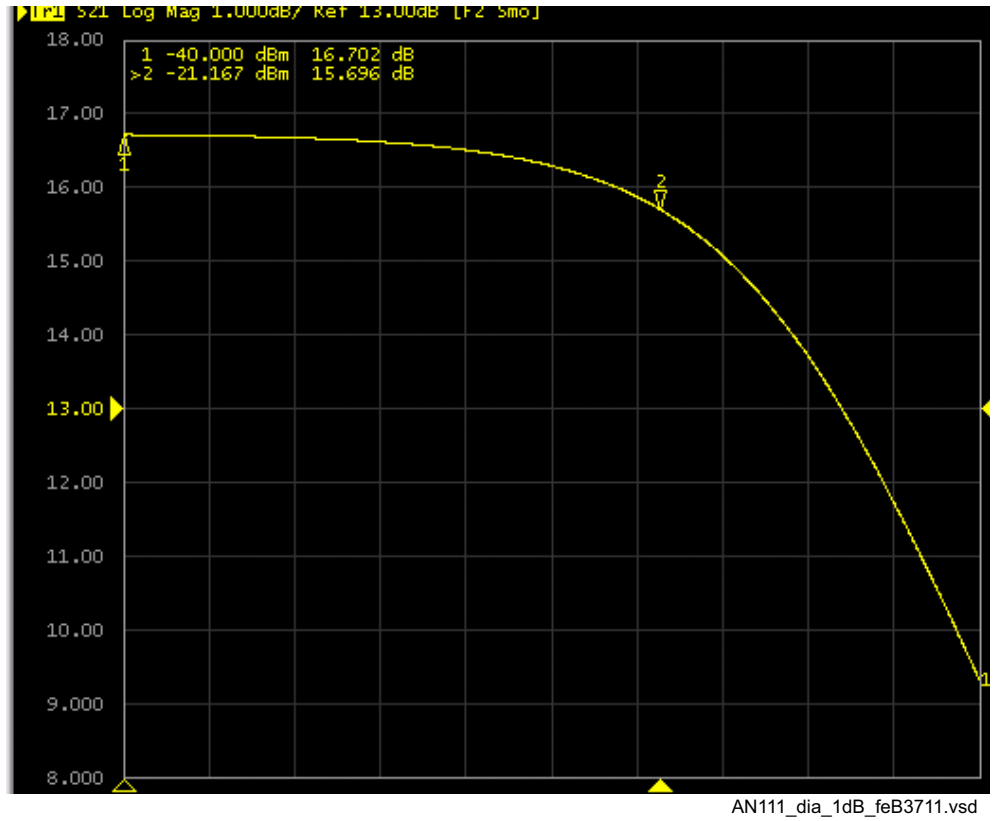

Figure 27 Input 1 dB compression of Front End (BFP540Esd Plus SAW Filter B3711)