A 35 dB Gain-Sloped LNB I.F. Amplifier for Direct Broadcast Satellite Television Applications using the BGA430 & BGB540 Silicon MMICs

- **Gain = 32 – 37 dB from 950 – 2150 MHz (positive gain slope)**

- **Low Power Consumption: 40mA at +5.0 Volts**

- **Exceptionally low Noise Figure: less than 3 dB**

- **Low Cost, Low Parts Count**

- **High Reverse Isolation**

- **Output Compression point: +1 dBm minimum (May be increased with higher DC bias level)**

- **Suitable for European, Asian & North American DBS LNB I.F. Amplifier Chains for 950 – 1450 and 950 – 2150 MHz**

1. Overview

Infineon's **BGA430 Broad Band High Gain Low Noise Amplifier** and **BGB540 Active Biased Transistor** are shown in an Intermediate-Frequency ("I.F.") amplifier application targeted for the I.F. chains of European, Asian and North American Direct-Broadcast Satellite (**DBS**) Low Noise Block Amplifier / Downconverters (**LNB**s).

A summary of key performance parameters for the complete LNB I.F. Amplifier is given in **Table 1** to the right. The reader is referred to **Appendix A** on page 21 for complete electrical data including minimum, maximum, mean value, and standard deviation for the lot of Printed Circuit Boards (PCBs) tested. **Appendix B** on page 22 gives information on performance over the –40 to +85 °C temperature range.

Section 2 of this applications note provides a brief description of the BGA430 and BGB540 MMICs. **Section 3** gives some general Direct Broadcast Satellite system information, and is included to provide a general background. **Section 4** provides details on the PC Board used, including photos, a Bill of Material (BOM) and a PCB cross-sectional diagram. **Section 5**

describes using the BGA430 MMIC as a stand-alone DBS I.F. Amplifier block, and covers design issues unique to BGA430. **Section 6** addresses the question "why might one want a positive gain slope I.F. Amplifier" and **Section 7** gives measurement results on the complete gain-sloped amplifier using both BGA430 & BGB540.

Table 1. Typical performance for the complete BGA430+BGB540 LNB I.F. Amplifier.

Conditions: Temperature=25°C, V=5.0 Volts, n=25 units, $Z_S = Z_L = 50\Omega$, network analyzer source power = -40 dBm

Parameter	Frequency, MHz		
	950	**1450**	**2150**
Input Return Loss, dB	26.0	27.3	12.0
Gain, dB	33.0	37.2	37.2
Reverse Isolation, dB	>50	>50	>50
Output Return Loss, dB	13.7	13.4	13.1
Noise Figure, dB	2.4	2.4	2.6
Output P_{1dB}, dBm	+1.7	+4.9	+7.9
Input IP_3, dBm	-20.8	-22.5	-18.9

Please note that the reference planes for all measurement data shown in **Table 1** are at the PC board's SMA RF connectors; e.g. no PCB loss is extracted from the numbers given.

## 2. Description of BGA430 and BGB540

The **BGA430** is a three-stage, 50 ohm, internally matched, unconditionally stable MMIC fabricated in Infineon's well-proven, consistent and cost-effective 25 GHz transition frequency (f_T) B6HF bipolar process. The BGA430 only requires three external elements – input / output DC blocking capacitors, and a single decoupling capacitor on the power supply pin. Depending on the particular LNB performance requirements, the BGA430 may be used as a stand-alone I.F. amplifier block, or together with the BGB540.

The **BGB540** is an unmatched, active-biased RF transistor produced in the 45 GHz f_T B6Hfe bipolar process. B6Hfe, derived from B6HF, is a more advanced process with higher achievable gains and lower noise figures. BGB540 uses an internal current mirror for DC biasing. This approach achieves some reduction in external component count due to elimination of a number of external DC bias circuit elements, while still preserving the flexibility inherent in a fully discrete transistor. The device bias current may be adjusted via a single external resistor. Furthermore, the internal current-mirror, being located on the same chip as the RF transistor cell, has excellent "thermal tracking" of the RF transistor cell, providing for a more stable DC operating point over temperature. The BGB540 preserves the cost-advantages of the simple 4-pin industry-standard SOT343 package.
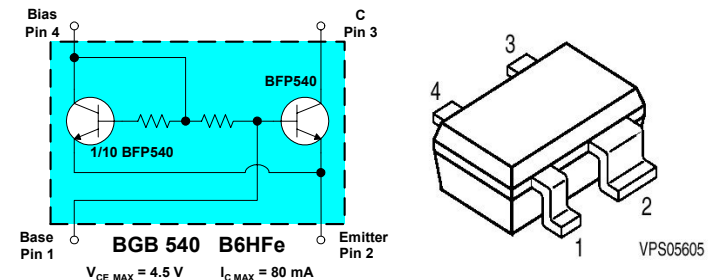
A block diagram and package drawing for the BGA430 and BGB540 are given in **Figures 1 & 2**, respectively. Note that for the BGB540, the emitter areas of the current-mirror transistor cell and the RF transistor cell are in the ratio of 1:10. To set DC bias current for the BGB540, one injects a current into pin 4, and the current drawn by the RF transistor cell is 10 times the current injected into pin 4, by virtue of the current-mirror principle. The simplest DC bias configuration for BGB540 involves using just a single resistor between the power supply and pin 4 – no RF choke or decoupling capacitor is required on pin 4. The value of this bias resistor – referred to as " R_{BIAS} " – required for a given device current can be determined from curves given in the BGB540 datasheet. For lower operating currents, the value of R_{BIAS} becomes large, and therefore R_{BIAS} in series with the power supply voltage behaves as a near-ideal constant-current source. Otherwise, the BGB540 is treated like a standard RF transistor, with the normal procedures for impedance matching, stability analysis, etc. being used.

Figure 1. BGA430 Block Diagram and Package (SOT363).

BGA430   (B6HF) V_{MAX} = 6.5 V, I_{MAX} = 35 mA
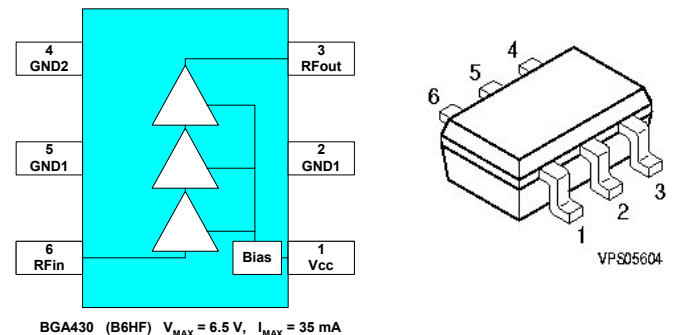
Figure 2. BGB540 Block Diagram and Package (SOT343).

BGB 540   B6HFe $V_{CE\ MAX}$ = 4.5 V $I_{C\ MAX}$ = 80 mA

3. General DBS System Information

A generic block diagram of a Direct Broadcast Satellite Low Noise Block Amplifier / Downconverter (LNB) is given in **Figure 3** on page 3. LNBs produced for the Direct Broadcast Satellite consumer electronics market are extraordinarily cost-sensitive, and cost issues are usually the primary consideration in the LNB design process.

A broadcast signal in the 12 GHz range is transmitted from an orbiting satellite towards the Earth's surface. There are two orthogonal parts
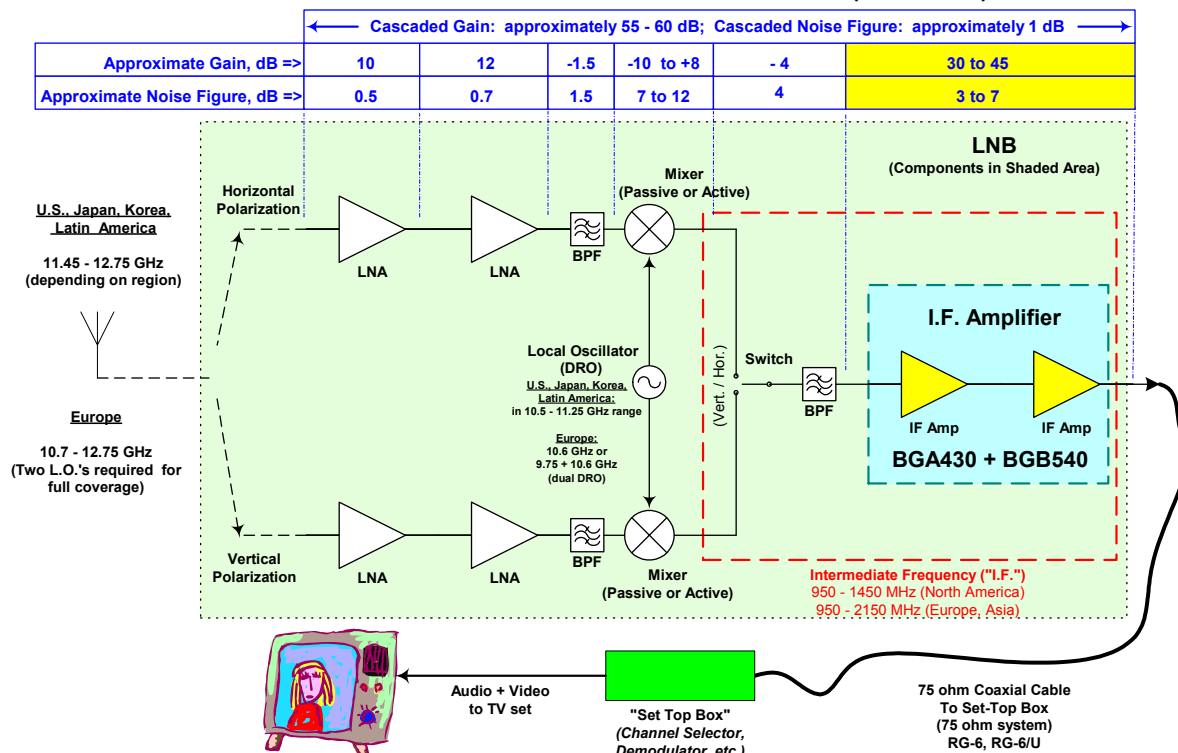
of the composite signal – a vertically polarized component, and a horizontally polarized component. The two polarizations enable more efficient use of the available bandwidth and power. (The isolation between "vertical" and "horizontal" radio signals permits a greater number of channels to be simultaneously broadcast within the available bandwidth than would otherwise be expected.) The satellite's transmitted signal is received by an earth-based antenna like that shown in the photo on page 1. The signal is focused by the parabolic "dish" antenna onto a waveguide integrated into the LNB. The received signal travels a short distance down the waveguide until reaching a waveguide-to-microstripline transition that carries the signal onto the LNB circuit board assembly.

The LNB must be able to receive channels on both the vertically and horizontally polarized signals – and one way to do this is to have essentially two different receiver front-ends as shown in **Figure 3** below.

Various approaches and switching schemes are employed in different LNB designs to enable the end user(s) to select between channels riding on either the horizontally or vertically polarized signals. Each approach has its own unique cost and performance trade-offs. Optimizing LNB architectures to achieve performance requirements while continuously reducing cost as new, higher-performance and lower cost semiconductor devices become available is a challenging task.

A further complication to the switching requirements is added if one wishes to have a "dual output LNB" – e.g. an LNB that can drive two different set-top boxes and television sets simultaneously, allowing each TV to display a different channel. ("Quad output" LNBs are also available). One possible switching scheme for a "single output LNB" is shown in **Figure 3**. Note that the vertical / horizontal switching is done at the I.F. Amplifier block. The **BGA430** and **BGB540** are shown in the shaded I.F. Amplifier section.

Figure 3. Generic Block Diagram, "Single Output" Direct Broadcast Satellite Television Block Downconverter (DBS LNB)

	Cascaded Gain: approximately 55 - 60 dB; Cascaded Noise Figure: approximately 1 dB					
Approximate Gain, dB =>	10	12	-1.5	-10 to +8	- 4	30 to 45
Approximate Noise Figure, dB =>	0.5	0.7	1.5	7 to 12	4	3 to 7

After the waveguide to microstrip transition, the signals enter a PC Board assembly. The signal is amplified in two or more low noise amplifier (LNA) stages and then hits a band pass filter. The LNAs provide enough gain to boost the level of the received signal such that the overall receiver noise figure is dominated by the LNA block itself. The LNA stages must have enough gain and a sufficiently low noise figure to minimize the noise floor for the entire receive chain. Achieving enough gain and a low enough noise figure at 12 GHz is costly, and anything that can reasonably be done to relax the requirements on the LNA section will reduce cost.

The LNA is then followed by a band pass filter (BPF) which provides for some rejection of out – of-band signals and noise, as well as image rejection. The amplified and filtered signal then enters the mixer stage.

The types of simple, inexpensive mixers likely to be used in an LNB will usually convert *both* the desired input signal (12 GHz in this case) and an undesired "image" frequency (10 GHz) to the intermediate frequency (1 GHz for this example). The band pass filter in front of the mixer stage can attenuate any undesired signals or noise present at the 10 GHz image frequency before it hits the mixer stage, preventing the undesired image from being down-converted on top of the desired, down-converted 12 GHz input signal. At present, most LNB manufacturers use one of three main types of mixers:

1. GaAs FET used as a simple active mixer

2. GaAs FET with no DC bias applied ("FET resistive mixer")

3. Schottky Diode based mixer

Some references for mixers are given in [1] and [2] at the end of this applications note.

The FET active mixer will usually have "conversion gain" while the FET resistive mixer or Schottky diode mixers have "conversion loss". Conversion gain or loss is simply the ratio of the amplitudes of the down-converted output I.F.

signal to the RF input signal. A poor noise figure in the mixer stage, as well as high conversion loss, places additional demands (and cost) on both the LNA block up front, as well as the I.F. amplifier which follows.

The down-converted I.F. signal undergoes further band pass filtering and then is amplified in the I.F. amplifier block. The I.F. amplifier is the focus of this applications note, and is the primary point of discussion regarding the BGA430 and BGB540 Silicon MMICs. The I.F. amplifier boosts the signal up to a reasonable input level for the set top box. It is worth noting that the system impedance in this area is 75 ohms, not 50 ohms, and that the coaxial cable typically used (RG-6, RG-6/U or sometimes RG-59) is very low cost, and has a relatively high attenuation per unit length a the intermediate frequency. Furthermore, the attenuation of the cable increases with increasing frequency – coaxial cable loss at 2150 MHz is higher than cable loss at 950 MHz. **Herein lies the reason for designing an I.F. amplifier with a gain slope that increases with increasing frequency – this positive gain slope in the I.F. amp will help to compensate out the negative gain slope of the coaxial cable and other RF front-end blocks**.

4. Information on Printed Circuit Board

The PC board used in this applications note was simulated within and generated from the **Eagleware GENESYS®** [3] software package. After simulations, CAD files required for PCB fabrication, including Gerber 274X and Drill files, were created within and output from GENESYS. Photos of the PC board are provided in **Figures 4, 5 and 6**. A cross-sectional diagram is given in **Figure 7**. A schematic diagram and a Bill Of Material (BOM) for the complete BGA430 + BGB540 I.F. Amplifier are given in **Figures 8 and 9**, respectively. The PC Board material used is standard FR4. Note that each MMIC may be tested individually; capacitor C3 (see schematic) may be positioned to "steer" the RF from the BGA430 output to the SMA connector on the bottom of the PCB, or, C3 may be used to link the track from this same RF connector to the input of the BGB540. When testing the

BGB540 stage alone, a zero-ohm "jumper" needs to be used in place of R2. The total PCB area consumed for the entire BGA430 + BGB540 I.F. Amplifier is approximately 0.585 x 0.180 inch / 14.9 x 4.6 mm, or approximately 70 mm^2. The total component count, including both Silicon MMICs, is 16. Note that PCB area and component count may be reduced markedly if the end user is able to satisfy his or her I.F. amplifier requirements by using the BGA430 as a stand-alone part. The next section describes the BGA430 as a stand-alone I.F. amplifier.
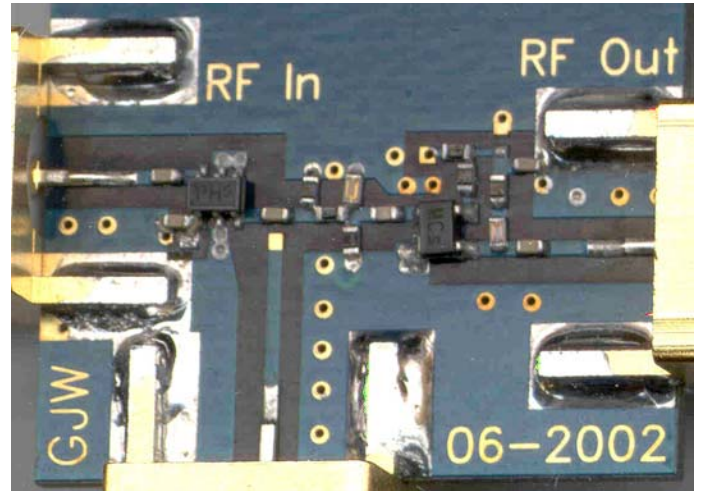
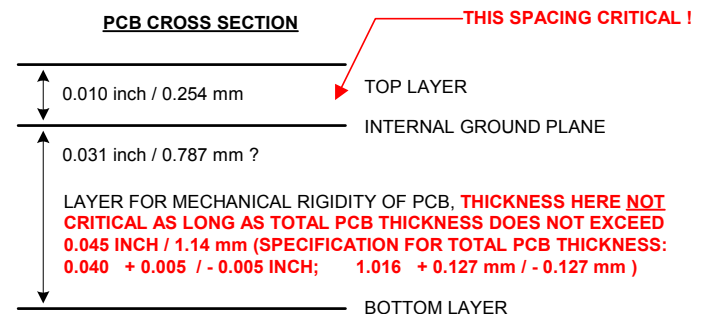**Figure 4. Top View of I.F. Amp PC Board.**

Figure 5. Bottom View of I.F. Amp PC Board
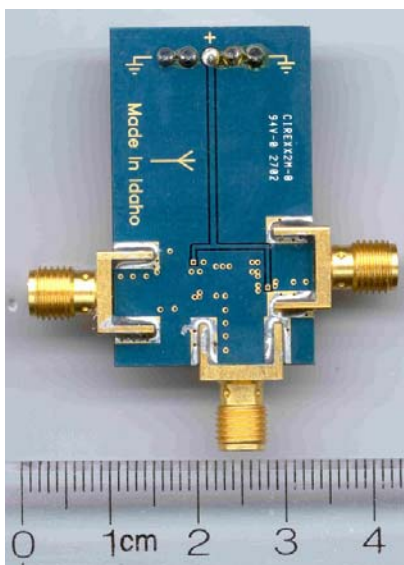
**Figure 6. Close-In Shot of PCB. BGA430 on left, BGB540 on Right.**

Figure 7. Cross-Section Diagram of I.F. Amplifier Printed Circuit Board.

5. Using the BGA430 as a Stand-Alone I.F. Amplifier Block

Provided that BGA430 gain magnitude, gain curve and output power are adequate for the user's LNB system requirements, BGA430 may be used as a very low-parts-count, low-cost stand-alone LNB I.F. amplifier over the 950 – 2150 MHz range. *Note that only 3 external elements are typically required with BGA430:* 1) an input DC blocking capacitor 2) an output DC blocking capacitor 3) an RF bypass / RF decoupling capacitor on the V_{CC} pin (Pin 1). **Table 2** on page 8 summarizes the BGA430's typical performance and **Figures 11 – 15** give network analyzer screen shots of input / output match, gain, and *(continued on page 7)*

Figure 8. Schematic Diagram of Complete BGA430 + BGB540 LNB I.F. Amplifier
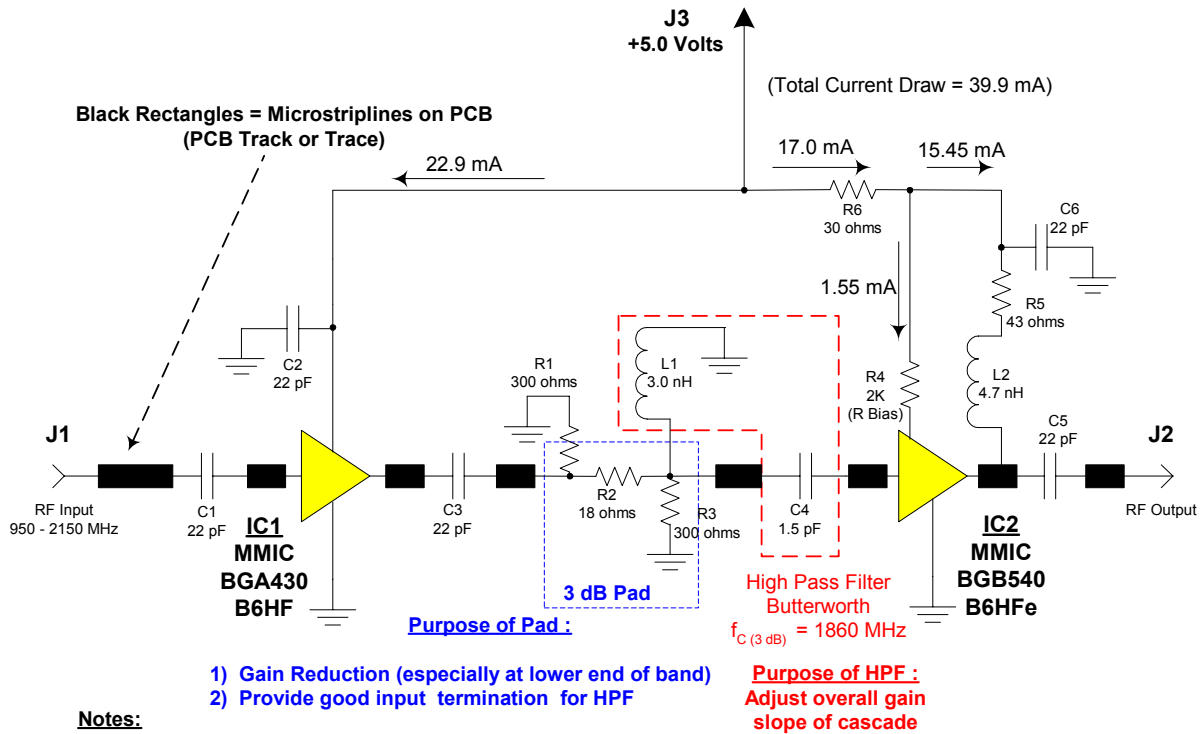
Notes:

1) Using C4 as both a DC block and as a Highpass Filter element enables the elimination of one capacitor
2) Bias current of Stage 2 (BGB540 MMIC) can be increased or decreased to vary overall output compression point
3) Stage 1 (BGA430) requires careful attention to proper grounding !

Figure 9. Bill Of Material (BOM) for Complete BGA430 + BGB540 LNB I.F. Amplifier

REFERENCE DESIGNATOR	VALUE	MANUFACTURER	CASE SIZE	FUNCTION
C1, C3, C5	22 pF	VARIOUS	0402	DC BLOCK
C2, C6	22 pF	VARIOUS	0402	RF BYPASS
C4	1.5 pF	VARIOUS	0402	DC BLOCK & HIGH PASS FILTER FUNCTION
L1	3.0 nH	MURATA LQP15M	0402	HIGH PASS FILTER FUNCTION
L2	4.7 nH	MURATA LQP15M	0402	"RF CHOKE" / DC FEED FOR BGB540, INFLUENCES BGB540 OUTPUT MATCH
R1, R3	300 OHMS	VARIOUS	0402	FOR 3 dB ATTENUATOR PAD
R2	18 OHMS	VARIOUS	0402	FOR 3 dB ATTENUATOR PAD
R4	2K	VARIOUS	0402	R_{BIAS} FOR IC2 (BGB540 MMIC) - SETS DEVICE CURRENT)
R5	43 OHMS	VARIOUS	0402	RF STABILITY AND OUTPUT MATCH FOR IC2 (BGB540)
R6	30 OHMS	VARIOUS	0402	DROP 5V SUPPLY TO ~ 4.5V. MAY BE OMITTED IF MAXIUM RATINGS OF IC2 ARE NOT EXCEEDED.
IC1	**-**	**INFINEON TECHNOLOGIES**	**SOT363**	**BGA430 Si MMIC, B6HF PROCESS**
IC2	**-**	**INFINEON TECHNOLOGIES**	**SOT343**	**BGB540 ACTIVE BIASED TRANSISTOR MMIC, B6HFe PROCESS**
J1, J2	-	JOHNSON 142-0701-841	-	RF INPUT / OUTPUT CONNECTOR
J3	-	AMP 5 PIN HEADER MTA-100 SERIES P/N 640456-5 OR 641215-5 (GOLD PLATING)	-	DC CONNECTOR PINS 1, 2, 4, 5 = GROUND PIN 3 = V_{CC}

reverse isolation. Note that all of these results are taken in a 50 ohm system, and that results in a 75 ohm system will differ slightly.

Circuit Design Issues Relevant to BGA430:

1) proper device grounding !!

2) proper bypassing of the V_{CC} pin !

The BGA430 is an extremely high gain device (>30 dB @ 1 GHz) contained within a single SMT package. As a result, casual or sloppy PCB layout techniques which add undesired parasitic inductance between BGA430 ground leads and PCB ground plane will add enough feedback to adversely alter the BGA430's gain and return loss. In cases of extremely poor grounding, sufficient feedback will be present to enable either gain "peaking" or even an oscillation. In addition, the V_{CC} pin (Pin 1) needs to be bypassed with a capacitor that, with its self-inductance taken into account, approximates a short-circuit in the 1 to 2 GHz range. Generally a 0603 or 0402 case-size chip capacitor in the range of 15 – 22 pF is sufficient. A photo of a bare I.F. Amp PC board is shown in **Figure 10**, with a close-in view of the BGA430 mounting area. Note that seven (7) ground vias are provided for the BGA430 ground pins, including three ground vias located immediately underneath the device. Note the two ground holes provided for the bypass capacitor C2 (22pF) on the BGA430 V_{CC} pin, and the close proximity of C2 to the V_{CC} pin.

To summarize:

- The user must avoid any additional parasitic ground inductance between BGA430 ground pins and PCB ground plane.   A sufficient number of ground vias need to be provided and these vias should be placed as close to the BGA430 as possible.

- BGA430 V_{CC} pin (Pin 1) must be bypassed carefully, and the bypass capacitor used must have its "cold" side well-grounded.

If these two suggestions are carefully followed, a low-cost, single device solution may be used for

some I.F. amplifier designs, requiring only 3 external elements.

Figure 10. BGA430 Mounting Position on PC Board. Compare unpopulated (above) to populated (below) PCB images. Note locations and number of ground vias near BGA430 MMIC. Pin 1 (V_{CC}) is pad at lower left.
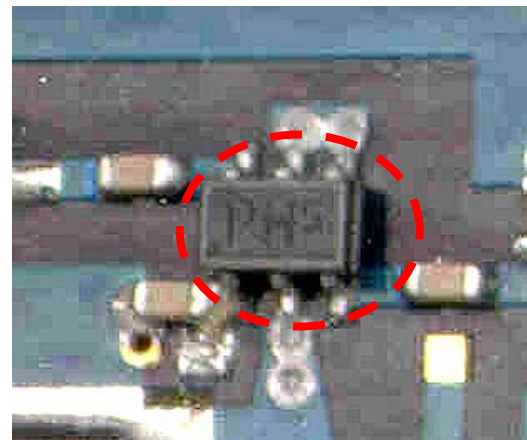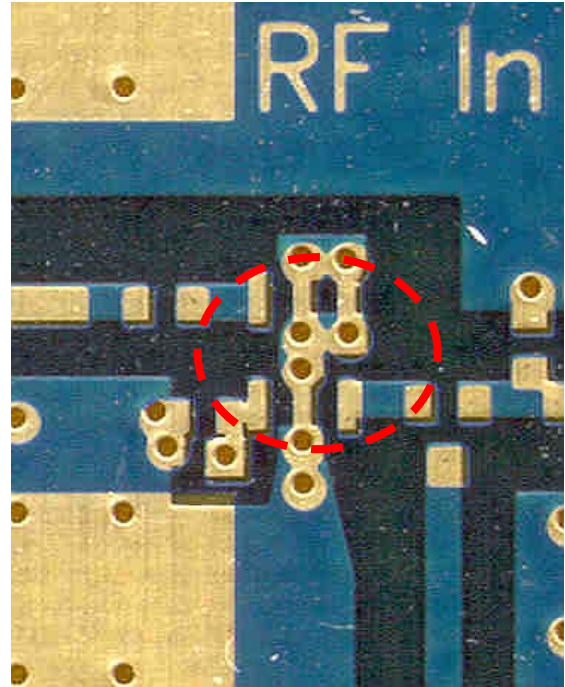
It needs to be pointed out that the BGA430 is designed to operate at a nominal supply voltage of +5 volts, with a current draw of approximately 23mA. However, if a higher output compression point is desired, the BGA430 may be safely run up to 6.5 volts, and maximum safe current is 35mA. If an adjustable output voltage regulator

is used in the LNB, and if a higher output power is required of the BGA430 than is available at the 5V, 23mA condition, the user has the option of simply cranking up the BGA430 supply voltage.

Table 2. Summary of stand-Alone BGA430 LNB I.F. Amplifier Performance.

Conditons: Temperature = 25°C, V = 5.0 Volts, PCB = Infineon P/N 430-051802 Rev B, $Z_S=Z_L=50$ Ω, network analyzer source power = -40 dBm.

Parameter	Frequency, MHz		
	950	**1450**	**2150**
Input Return Loss, dB	11.1	12.2	12.4
Gain, dB	33.4	33.2	27.8
Reverse Isolation, dB	40.5	42.5	46.1
Output Return Loss, dB	13.7	13.4	13.1
Output P_{1dB}, dBm	+3.2	+3.9	+3.2

Figure 11. Stand-Alone BGA430 Amp, Input Return Loss.
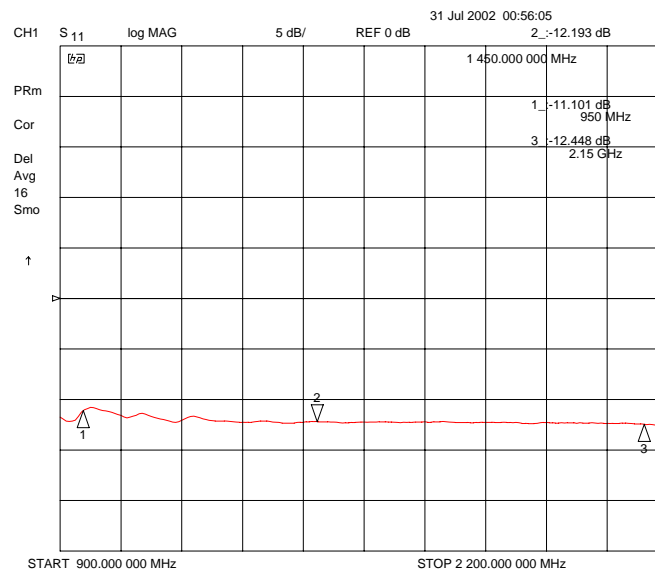
Figure 12. Stand-Alone BGA430 Amp, Input Return Loss, Smith Chart. Reference Plane = PCB Input SMA Connector.
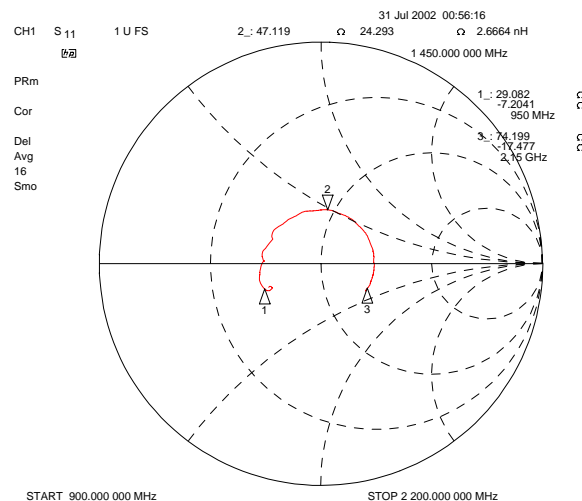
Figure 13. Stand-Alone BGA430 Amp, Forward Gain.

```
                                          31 Jul 2002  00:56:41
CH1   S 21      log MAG      5 dB/      REF 30 dB           2_: 33.205 dB
      ᡌᆮ                                      1 450.000 000 MHz
PRm                                                  1_: 33.447 dB
                                                           950 MHz
Cor   SCALE                                          3_: 27.765 dB
                                                           2.15 GHz
Del   5 dB/div
Avg
16
Smo


                                      2
↑
      1

▷


                                                              3




START  900.000 000 MHz                    STOP 2 200.000 000 MHz
```
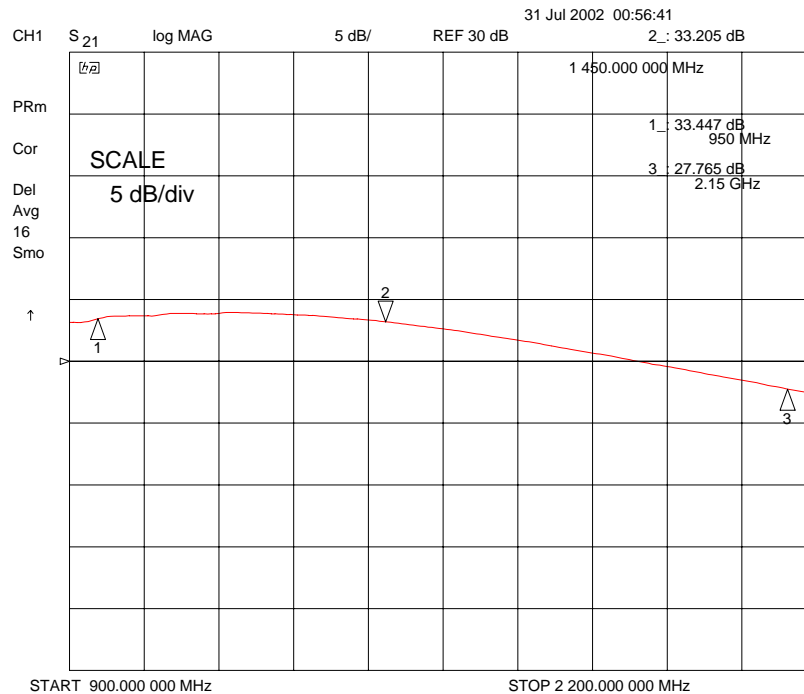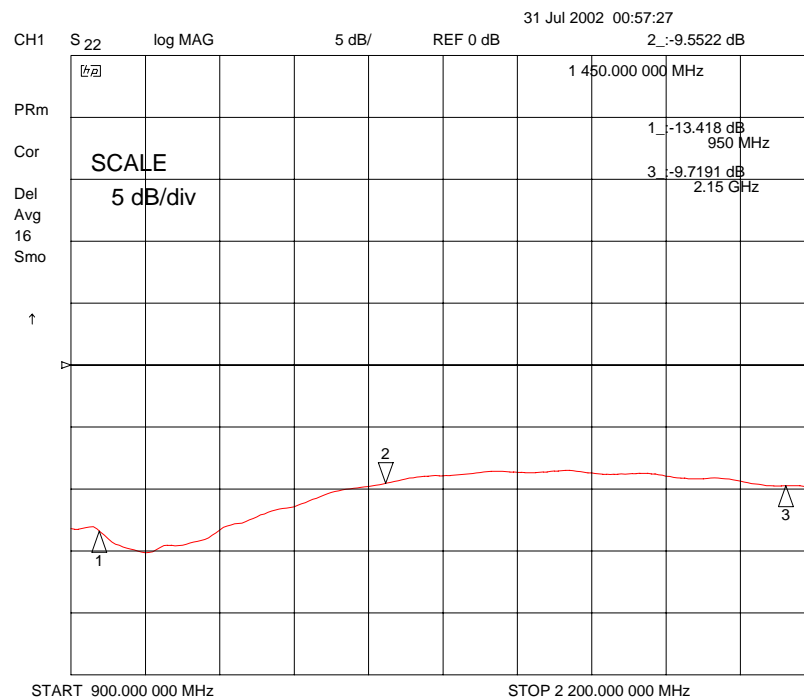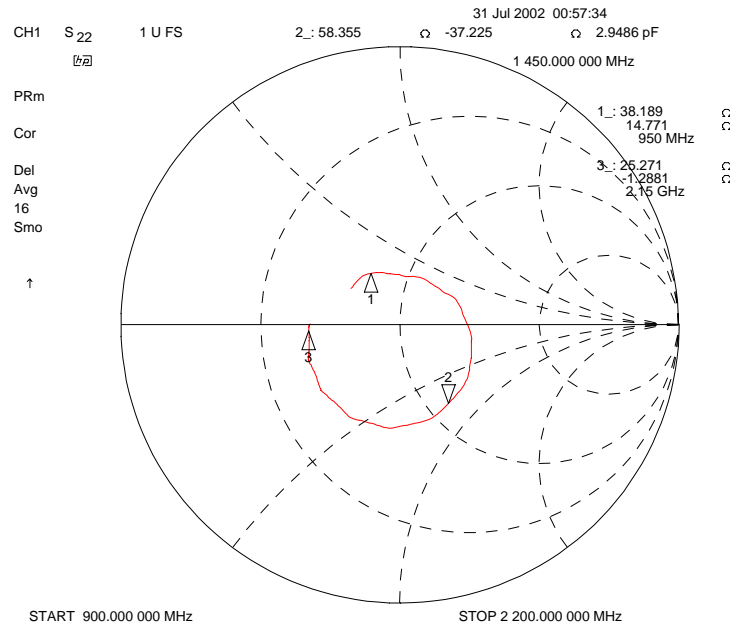
Figure 14. Stand-Alone BGA430 Amp, Output Return Loss.

```
                                          31 Jul 2002  00:57:27
CH1   S 22      log MAG      5 dB/      REF 0 dB            2_:-9.5522 dB
      ᡌᆮ                                      1 450.000 000 MHz
PRm                                                  1_:-13.418 dB
                                                           950 MHz
Cor   SCALE                                          3_:-9.7191 dB
                                                           2.15 GHz
Del   5 dB/div
Avg
16
Smo


↑

▷

                                      2
                                                              3
      1




START  900.000 000 MHz                    STOP 2 200.000 000 MHz
```

**Figure 15. Stand-Alone BGA430 Amp, Output Return Loss, Smith Chart.
Reference Plane = PCB Output SMA Connector.**

6.   Why a Positive Gain Slope LNB I.F. Amplifier?

The question arises: why would one want an I.F. amplifier with a positive gain slope? The reader is referred to **Figures 16 – 20** on pages 11 – 13. Two points are worth noting:

I.   The return loss of this 75 ohm cable appears to be quite reasonable in a 50 ohm measurement system (partly due to the cable's insertion loss characteristic)

II.   The insertion loss of the 15.2 meter length of cable _increases with increasing frequency_. (**Figures 18 & 20**.)

A 15 meter length of coaxial cable has a negative gain slope of approximately 2 dB across the 950 – 2150 MHz range. An additional 15 meter section of lower-cost coax cable (RG-6) was attached via a "barrel" connector to the first section, making a 30.4 meter cable run, which was then also tested. For a 30.4 meter / 100 foot length of cable, there is a delta of approximately 4 dB in insertion loss as we move from 950 to 2150 MHz.

If an LNB I.F. Amplifier were made with a positive gain slope, the net gain across the I.F. bandwidth could be 'flattened out' somewhat, and the range of input power that the set-top box demodulators need to work over could be reduced. *Furthermore, this description of coaxial cable negative gain slope only considers gain decrease with increasing frequency or "gain roll-off" in the cable itself. In all likelihood, the LNB's 12 GHz LNA block and mixer stage will have a gain roll-off of their own, further worsening the overall net negative gain slope of the entire LNB and coax cable assembly taken together.*

Table 3 on page 13 summarizes coaxial cable insertion loss and return loss for both 15.2 meter and 30.4 meter cable runs. The next section describes the complete BGA430 + BGB540 LNB I.F. Amp with positive gain slope.
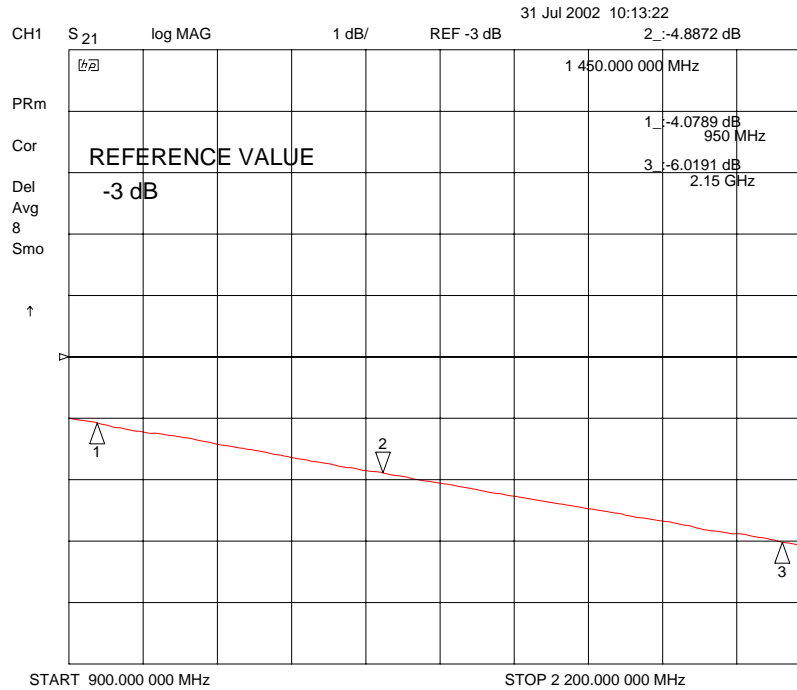
Figure 16. 15.2 meter / 50 foot section of commercial 75 ohm RG-6 coaxial cable being tested. Note measurement system impedance is 50 ohms.
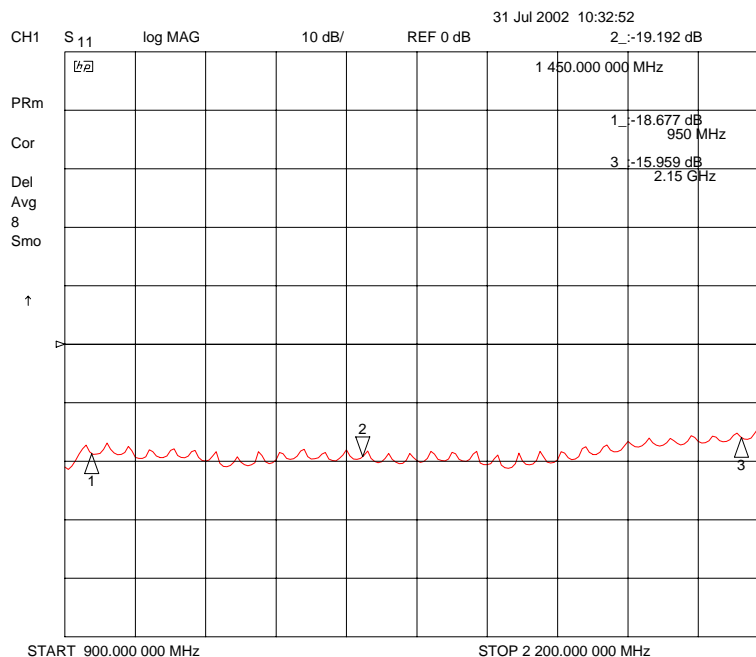

Figure 17. Return Loss of 15.2 meters / 50 foot section of 75 ohm RG-6 coaxial cable. Measurement made in 50 ohm system.
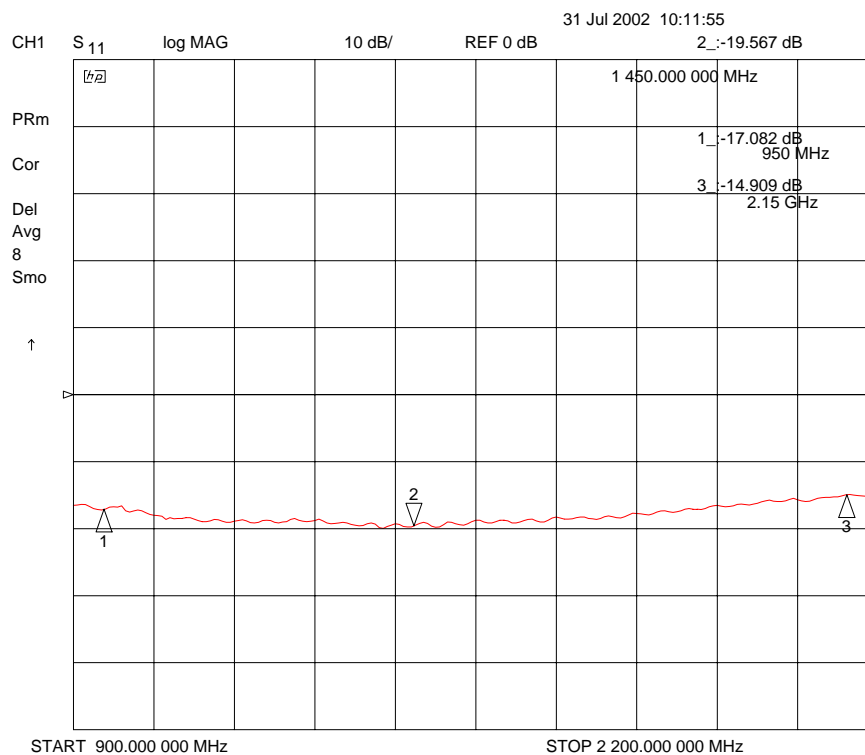
Figure 18. Insertion loss of 15.2 meter / 50 foot section of 75 ohm RG-6 coax cable. Measurement system impedance is 50 ohms.   Gain slope for this section is approximately   - 1.62 dB / GHz.

31 Jul 2002 10:13:22

CH1 S$_{21}$ log MAG   1 dB/   REF -3 dB   2_:-4.8872 dB

1 450.000 000 MHz

PRm

Cor   REFERENCE VALUE   1_:-4.0789 dB
                                                        950 MHz
Del   -3 dB   3_:-6.0191 dB
Avg   2.15 GHz
8
Smo

↑

▷

START 900.000 000 MHz   STOP 2 200.000 000 MHz

Figure 19. Return Loss of a 30.4 meter / 100 foot section of 75 ohm coaxial cable. Measurement system impedance is 50 ohms.

31 Jul 2002 10:32:52

CH1 S$_{11}$ log MAG   10 dB/   REF 0 dB   2_:-19.192 dB

1 450.000 000 MHz

PRm

Cor   1_:-18.677 dB
                                                        950 MHz
Del   3_:-15.959 dB
Avg   2.15 GHz
8
Smo

↑

▷

START 900.000 000 MHz   STOP 2 200.000 000 MHz

Figure 20. Insertion loss of 30.4 meter / 100 foot section of 75 ohm coaxial cable. Measurement system impedance is 50 ohms. Gain slope for this section is -3.55 dB / GHz.
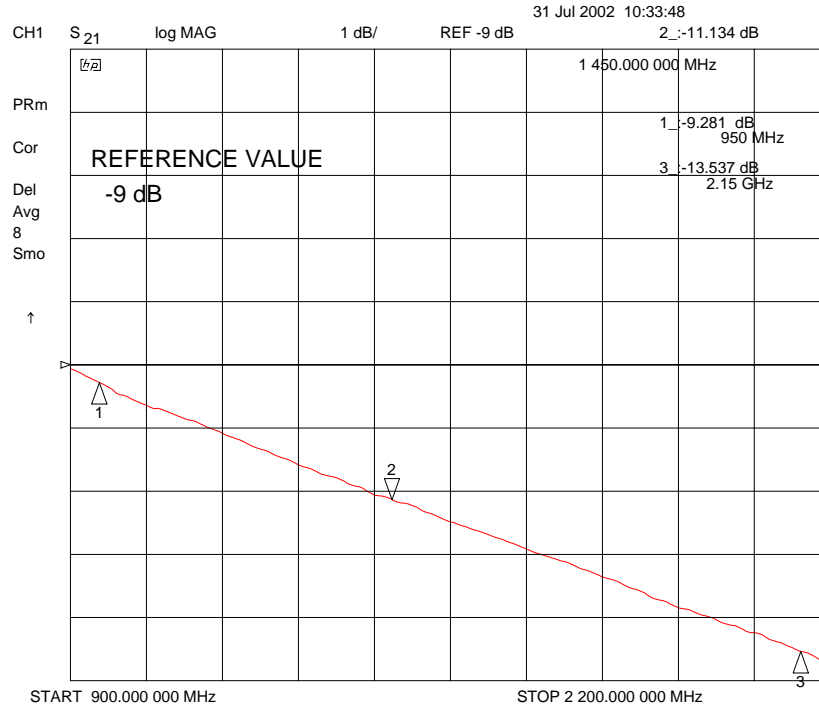
Table 3. Return Loss & Insertion Loss vs. Frequency, 15.2 m / 50 ft   and 30.4 m / 100 ft sections of 75 ohm coaxial cable.

Cable Length m / ft	Parameter	Frequency, MHz		
		950	1450	2150
15.2 / 50	Input Return Loss, dB	17.1	19.6	14.9
15.2 / 50	Insertion Loss, dB	-4.1	-4.9	-6.0
30.4 / 100	Input Return Loss, dB	18.7	19.2	16.0
30.4 / 100	Insertion Loss, dB	-9.3	-11.1	-13.5

7. Complete Gain-Sloped LNB I.F. Amplifier with both BGA430 & BGB540 MMICs

The basic approach taken for the complete I.F. Amp was to create a positive gain slope (gain increases with increasing frequency) via use of a simple, low-cost High Pass Filter (HPF) between the BGA430 and BGB540 MMICs. The HPF between the two MMICs has the effect of reducing the overall amplifier gain below the filter's cutoff frequency, allowing one to achieve a positive gain slope.   Please refer to the Schematic Diagram, **Figure 8** on page 6. Shunt inductor L1 and series capacitor C4 form a high-pass filter with a 3 dB corner frequency near 1860 MHz. Computer simulation in Eagleware's GENESYS® package, which includes filter synthesis tools, permitted fast and easy design optimization for the best overall amplifier gain response. To give the reader an idea of the interstage high pass filter's shape, please refer to **Figure 21** on the next page. This is a plot of simulated filter insertion loss and return loss which was exported from GENESYS.

Figure 21. Simulated Return Loss and Insertion Loss for 2 – Element High Pass Filter. Note insertion loss = 10.3 dB at 950 MHz.
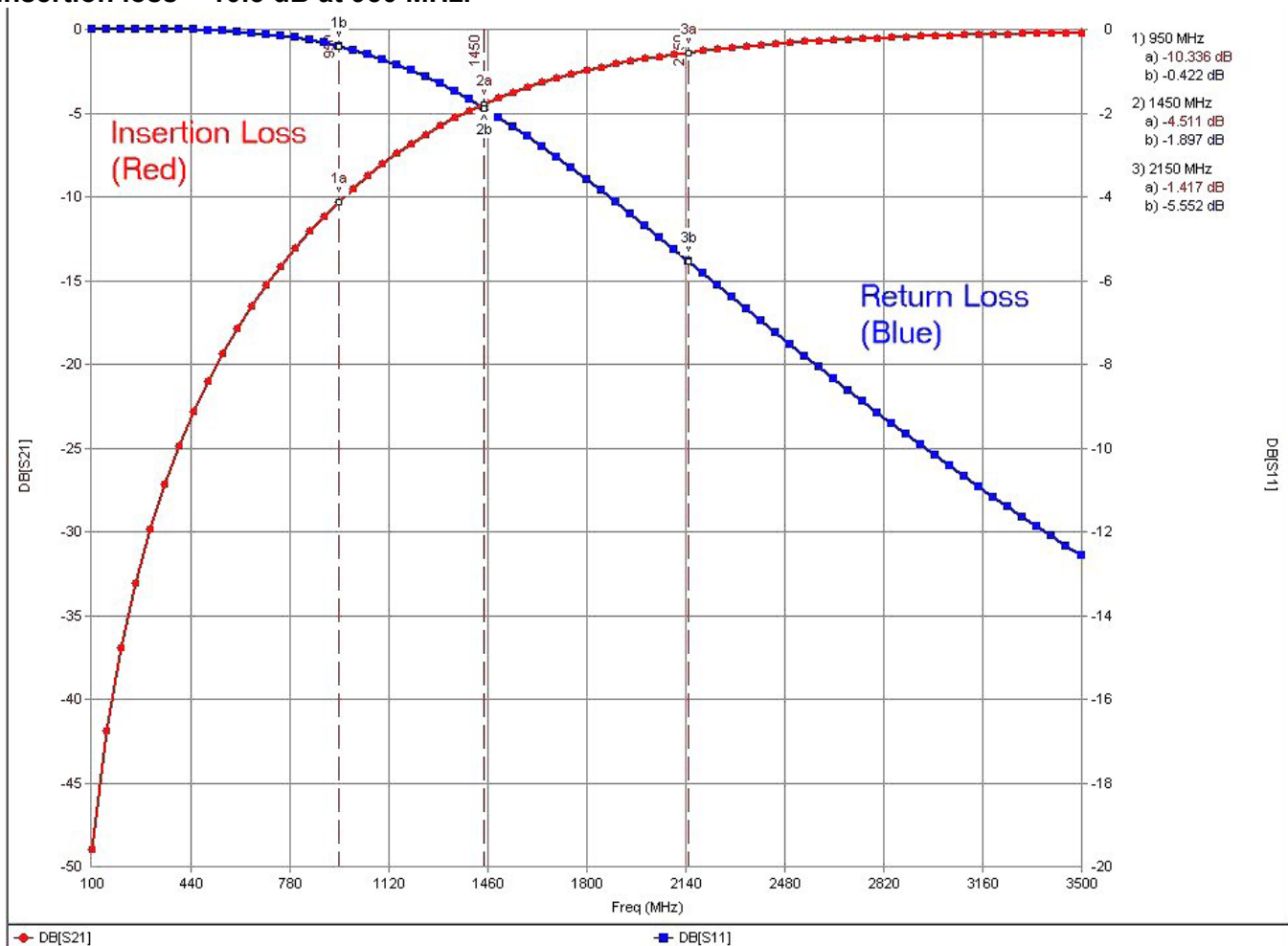
The entire amplifier with the high pass filter was optimized in simulations. A significant improvement in I.F. amplifier gain slope was achieved. Please refer to **Figures 22 – 29** for Return Loss, Gain and Reverse Isolation plots of the complete BGA430 + BGB540 I.F. Amplifier, with and without the I.F. Amp driving a 30 meter length of coaxial cable.

For the complete I.F. Amplifier, there is a difference of about 4 dB in gain between 950 and 2150 MHz, with a *positive slope* – and that the 30.4 meter / 100 foot length of 75 ohm coaxial cable has about a 4 dB difference in insertion loss between 950 and 2150 MHz, with a *negative slope.*

To see the net gain response of the gain-sloped BGA430 + BGB540 I.F. Amplifier together with

30.4 meters / 100 feet of 75 ohm coaxial cable, this combination was measured in a network analyzer. Please refer **to Figure 23** on page 16. A plot of the resulting gain response of the complete gain-sloped BGA430 + BGB540 I.F. Amp driving 30 meters / 100 feet of coaxial cable is given. *When this I.F. Amp drives 30 meters of 75 ohm coax, the gain at 950 and 2150 MHz is virtually identical, with a 3 dB 'hump' or rise at mid band.*

The use of a high pass filter to achieve a positive gain slope does limit the available output compression point at the lower end of the frequency range (950 MHz). However, some of the output power capability could be bought back by running the BGA430 at a higher bias voltage than 5.0 volts as is done here, since the BGA430 can safely tolerate up to 6.5 volts.
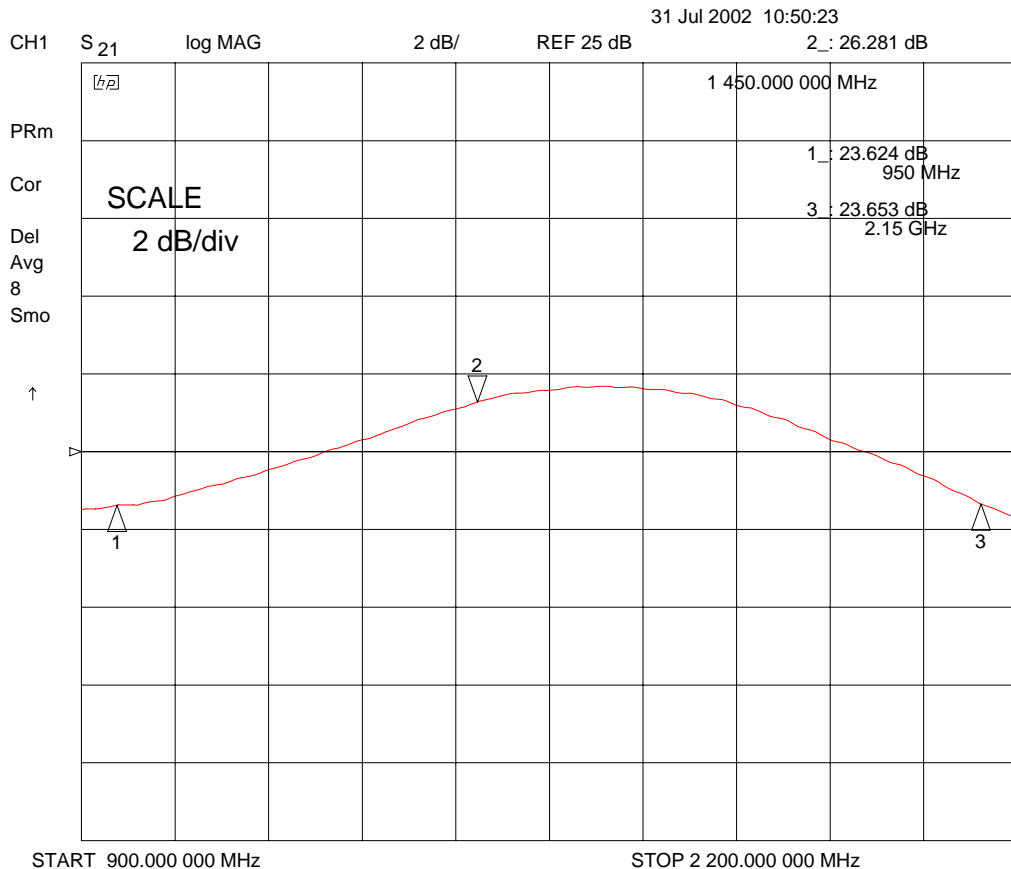
Figure 22. Gain of Complete Gain-Sloped BGA430 + BGB540 LNB I.F. Amplifier. Note positive gain slope.
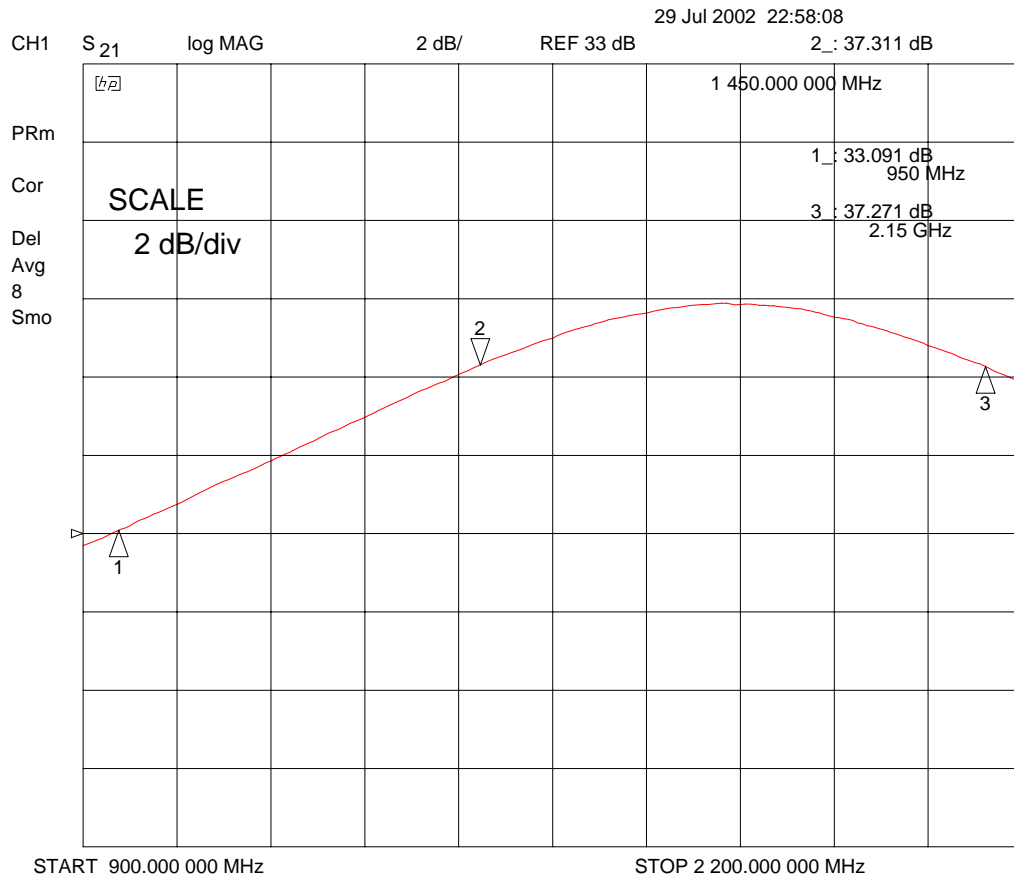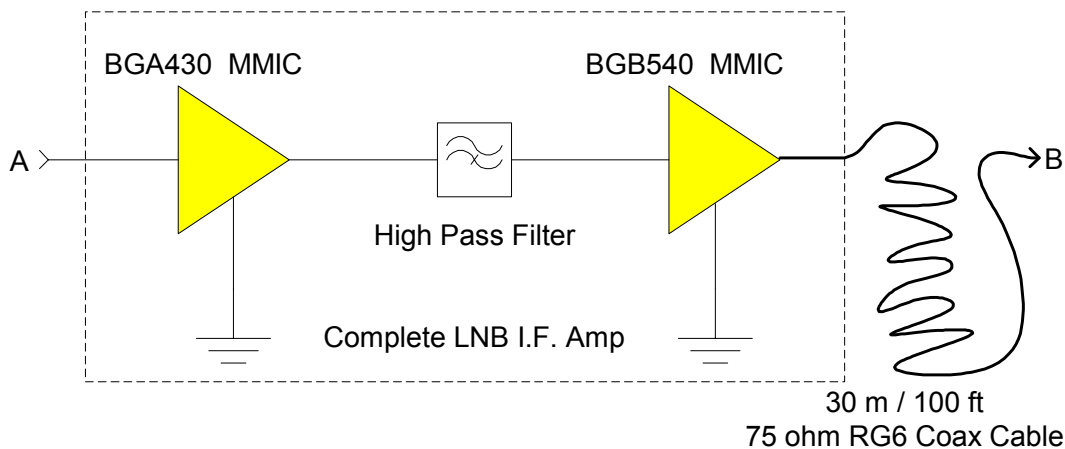

Gain Plot for Figure 22 is taken between points 'A' and 'B'
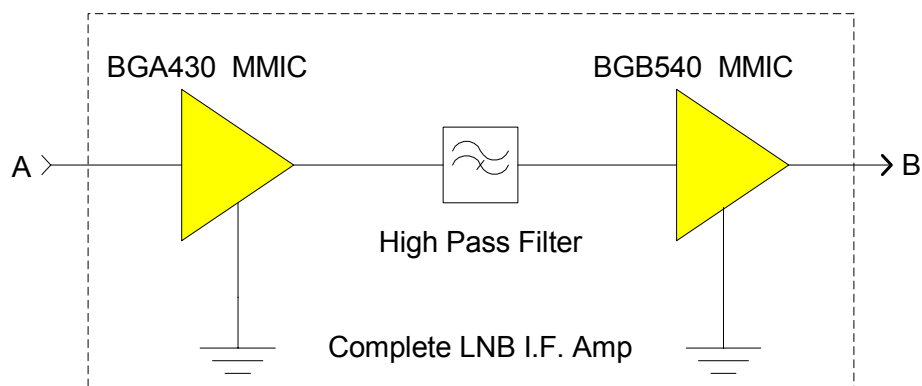
Figure 23. Network Analyzer Screen Shot of Complete Gain-Sloped BGA430 + BGB540 LNB I.F. Amplifier driving 30 meters / 100 feet of 75 ohm RG-6 Coaxial Cable. The resulting net gain at 950 and 2150 MHz are nearly equal in value, with net gain at 950 MHz = 23.6 dB, and net gain at 2150 MHz = 23.7 dB. The mid band "hump" in gain is approximately 3 dB. Before attaching the 30 meter length of cable to the output of the complete BGA430 + BGB540 I.F. Amplifier, the Amplifier Gain was 33 dB at 950 MHz and 37 dB at 2150 MHz.

31 Jul 2002 10:50:23

| CH1 | S 21 | log MAG | 2 dB/ | REF 25 dB | 2_: 26.281 dB |

1 450.000 000 MHz

PRm

Cor   SCALE

Del   2 dB/div

Avg
8
Smo

1_: 23.624 dB
    950 MHz

3_: 23.653 dB
    2.15 GHz

2

1

3

START 900.000 000 MHz

STOP 2 200.000 000 MHz

Gain Plot for Figure 23 is taken between points 'A' and 'B'

BGA430 MMIC   BGB540 MMIC

A

B

High Pass Filter

Complete LNB I.F. Amp

30 m / 100 ft
75 ohm RG6 Coax Cable

An advantage of either the stand-alone BGA430 or BGA430 + BGB540 I.F. Amp solution is the exceptionally low noise figure provided. The complete amplifier with the gain-sloping high pass filter has a noise figure of well under 3 dB. A plot of measured noise figure for one complete unit may be viewed in **Appendix C** on page 23. Depending on the gain and noise figure performance of the LNB's Low Noise Amplifier and Mixer sections, the excellent noise figure of the I.F. amplifier presented here could provide additional design margin for receiver sensitivity, and possibly enable the use of lower cost approaches for the LNA and mixer stages.

Conclusion

The BGA430 and BGB540 both provide a cost-effective and flexible solution for today's price-sensitive Direct Broadcast Satellite LNB I.F. Amplifier designs. A simple, low-cost approach was shown for achieving a positive gain slope in a 950 – 2150 MHz I.F. Amplifier. The BGA430 used as a stand-alone I.F. Amplifier requires only 3 external components, and the complete, gain-sloped I.F. Amplifier using both BGA430 and BGB540 with an interstage high pass filter allows the LNB designer to compensate for overall LNB gain roll-off in the Intermediate Frequency range, where gain roll-off compensation is easier and less costly to achieve than at the 12 GHz RF input frequency

range. Additional output power may be had from the BGA430 by running it up to a maximum of +6.5 volts. The exceptionally low noise figure of the I.F. Amplifier presented – under 3 dB – may help the LNB designer achieve additional sensitivity margin for his or her product.

The Applications Board shown in this Applications Note is available from Infineon Technologies.

References

[1] Mass, Stephen A. "Microwave Mixers", Second Edition. Artech House, 1993. (General reference is on mixers, including the use of FETs as active or resistive mixers).

[2] Mass, Stephen A. "The RF and Microwave Design Cookbook", First Edition, Artech House, 1998. ISBN 0890069735. Another reference on mixers, including single-device FET mixers.

[3] Eagleware Corporation, 653 Pinnacle Court, Norcross, GA 30071 USA. Tel: +1.678.291.0995 **http://www.eagleware.com** Eagleware software suite GENESYS Version 8 was used in all simulation, synthesis, and PC board CAD file generation done for the circuit described in this Applications Note.

Performance Plots of complete LNB I.F. Amplifier, and Appendixes A – C begin on the following page.

Figure 24. Input Return Loss of the complete BGA430 + BGB540 I.F. Amplifier. (No coaxial cable is included).
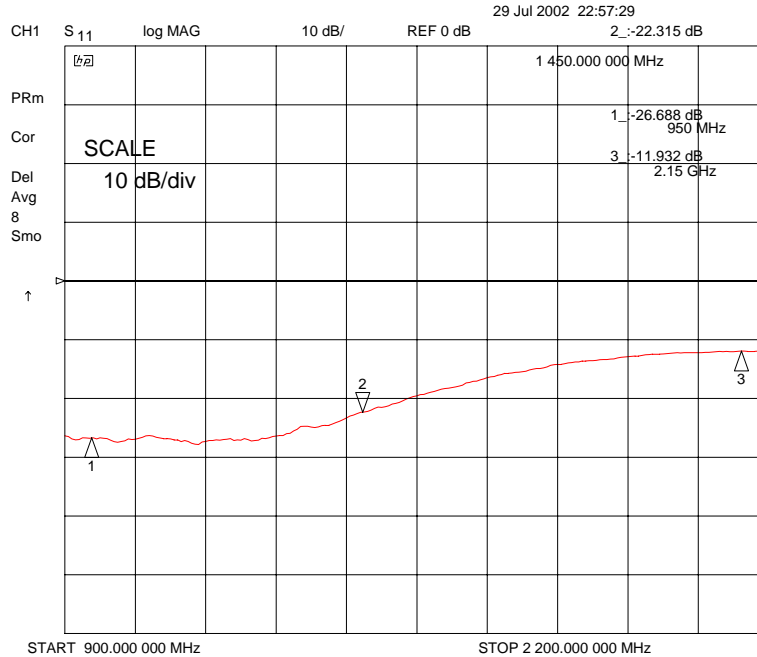
Figure 25. Input Return Loss of the complete BGA430 + BGB540 I.F. Amplifier, Smith Chart. Reference Plane = PC Board Input SMA RF Connector. (No coaxial cable is included).
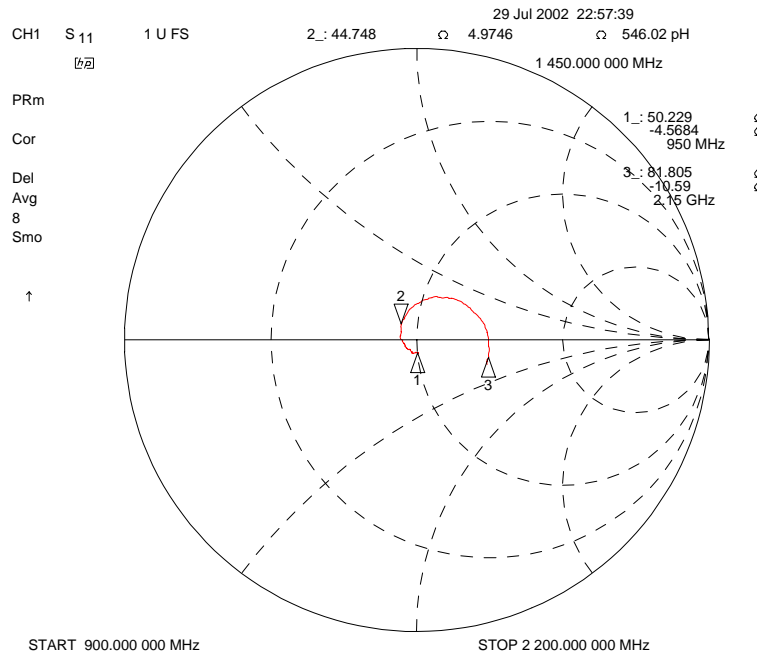
Figure 26.   Forward Gain, complete BGA430 + BGB540 I.F. Amplifier.   (No coaxial cable is included). Note positive gain slope.

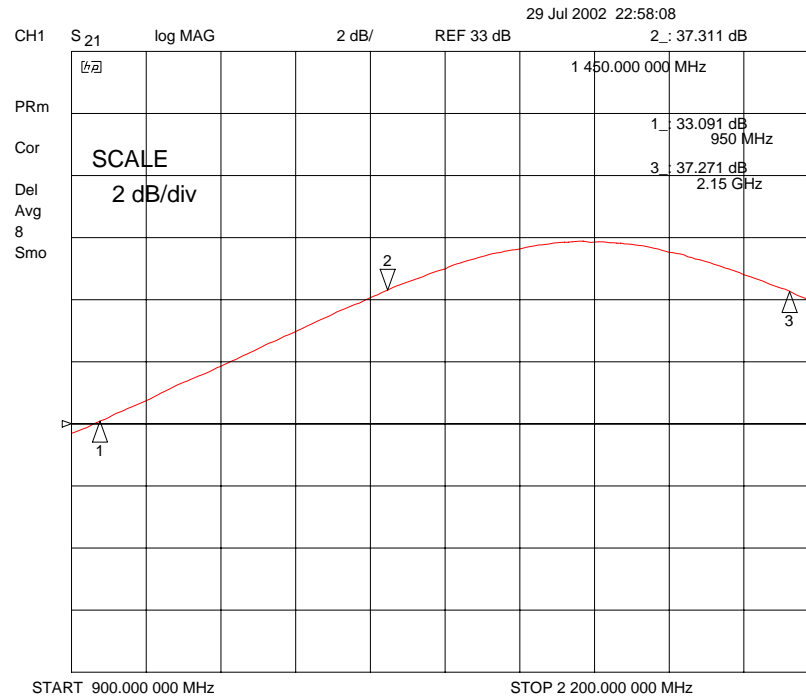**Figure 27.   Reverse Isolation, complete BGA430 + BGB540 I.F. Amplifier.   (No coaxial cable is included).**

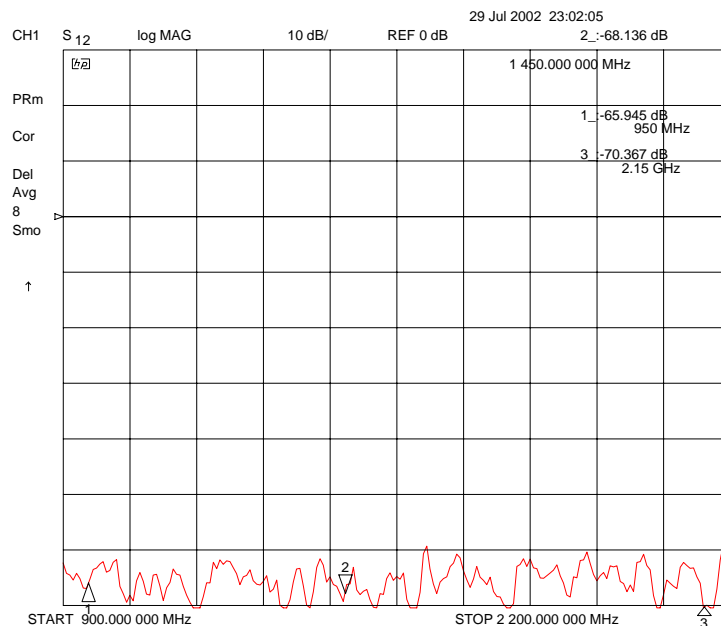**Figure 28. Output Return Loss, complete BGA430 + BGB540 I.F. Amplifier. (No coaxial cable is included).**

Figure 29. Output Return Loss, complete BGA430 + BGB540 I.F. Amplifier, Smith Chart. Reference Plane = PC Board Output SMA RF Connector. (No coaxial cable is included).
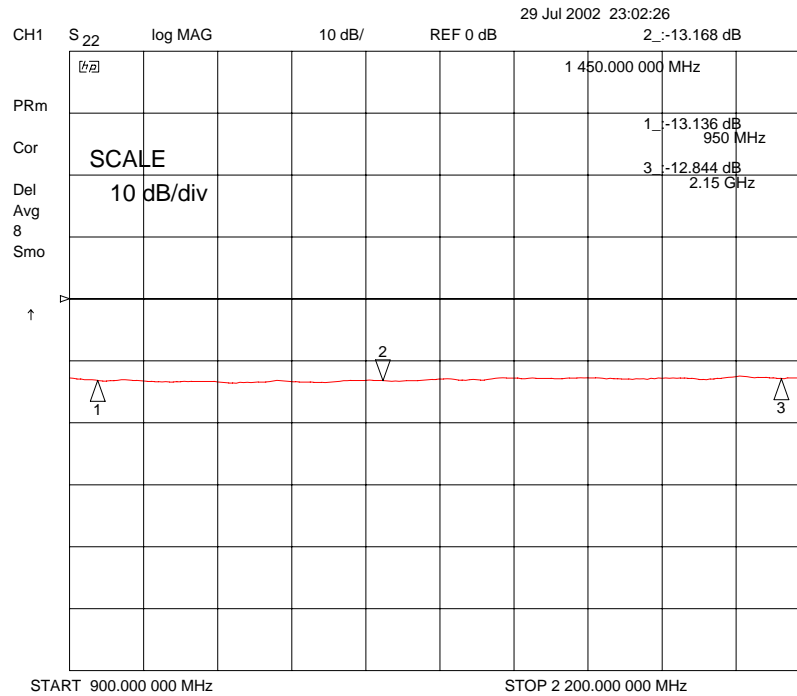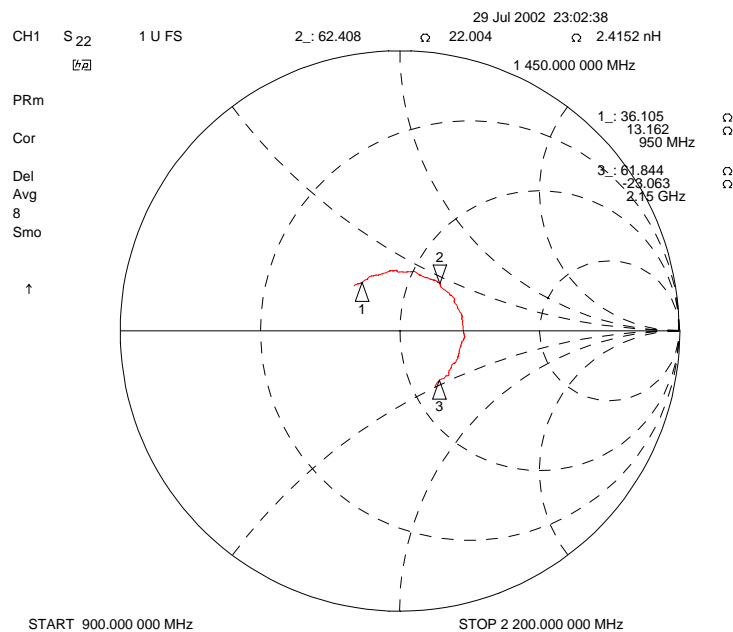
Appendix A. Data on 25 LNB I.F. Amplifier Circuit Boards, 430-051802 Rev B, taken randomly from a lot of 40 units. All data taken at room temperature (25°C).

Board S/N	dB[s11]²			dB[s21]²			dB[s22]²			Noise Figure, dB			Output 1dB Compression Point, dBm			Current Consumption mA
	950 MHz	1450 MHz	2150 MHz	950 MHz	1450 MHz	2150 MHz	950 MHz	1450 MHz	2150 MHz	950 MHz	1450 MHz	2150 MHz	950 MHz	1450 MHz	2150 MHz	
001	25.9	18.4	10.2	32.9	37.6	37.3	13.4	13.2	13.4	2.3	2.3	2.5	+1.5	+4.7	+7.7	40.0
002	26.2	31.9	12.2	32.7	36.8	37.2	13.2	13.2	13.2	2.5	2.5	2.6	+1.7	+4.7	+8.0	40.3
003	27.2	30.8	13.4	32.9	37.0	37.0	13.2	12.9	12.9	2.4	2.4	2.5	+1.9	+5.0	+8.1	40.8
004	26.1	25.8	11.4	33.1	37.4	37.4	13.3	12.8	12.6	2.3	2.3	2.5	+1.9	+4.9	+8.0	41.0
007	26.7	22.5	12.1	33.0	37.2	37.2	13.3	13.1	13.0	2.3	2.4	2.5	+1.7	+4.7	+7.9	40.8
009	27.0	28.1	12.1	32.7	36.9	37.0	13.4	13.3	13.0	2.3	2.4	2.5	+1.5	+6.8	**+7.8**	39.9
010	25.3	22.5	11.5	33.0	37.4	37.3	13.3	12.8	12.6	2.9	3.1	3.3	+1.6	+4.8	+7.9	40.7
011	24.1	38.1	11.9	33.0	37.2	37.0	13.5	13.6	13.3	2.3	2.4	2.5	+1.8	+5.0	+8.0	40.5
012	27.1	29.1	12.3	32.7	36.7	37.2	13.4	13.2	13.0	2.2	2.3	2.4	+1.7	+4.9	+8.2	40.9
013	24.6	30.2	12.6	32.8	36.9	36.8	13.6	13.4	12.9	2.3	2.4	2.5	+1.2	+4.2	+7.4	39.4
014	26.2	29.4	11.9	32.8	36.8	37.1	13.2	12.9	12.9	2.4	2.4	2.5	+1.6	+5.0	+7.9	40.2
015	25.0	33.4	12.6	32.7	36.7	36.7	13.2	12.7	12.5	2.4	2.4	2.5	+1.7	+4.9	+7.9	40.7
016	26.9	22.9	11.6	33.1	37.5	37.6	13.3	13.3	13.1	2.3	2.3	2.4	+2.0	+5.3	+8.2	41.4
017	26.3	25.3	12.6	33.1	37.5	37.4	13.7	13.7	14.1	2.3	2.4	2.5	+1.4	+4.5	+7.7	39.7
019	27.0	24.4	11.7	32.8	37.2	37.1	13.5	13.2	12.9	2.3	2.3	2.5	+1.7	+4.7	+7.8	40.4
022	27.4	25.9	13.0	32.9	37.1	37.3	13.2	12.8	13.1	2.3	2.4	2.5	+1.7	+4.8	+7.8	40.5
023	24.4	28.1	12.7	34.1	38.2	37.8	21.8	19.8	15.9	2.4	2.4	2.6	+2.9	+5.1	+7.7	40.6
027	26.2	32.6	13.0	32.7	36.7	36.9	13.0	12.7	12.6	2.6	2.7	2.8	+1.7	+4.8	+7.9	40.6
028	27.6	27.5	12.5	33.1	37.2	37.2	13.7	13.5	12.7	2.3	2.4	2.5	+1.7	+4.7	+7.8	40.3
029	27.9	23.7	11.1	33.2	37.7	37.6	13.5	13.5	13.8	2.4	2.4	2.5	+2.0	+5.1	+8.2	40.4
031	25.5	32.4	11.5	32.5	36.8	37.4	13.4	13.4	13.1	2.8	3.0	3.1	+1.6	+4.6	+7.9	40.0
033	25.6	23.0	11.7	32.8	37.2	37.3	13.0	12.9	13.2	2.3	2.3	2.5	+1.7	+4.8	+7.9	40.7
036	23.9	19.5	11.2	33.4	37.8	37.3	13.8	13.5	12.8	2.3	2.3	2.5	+1.6	+4.7	+7.9	40.6
037	24.7	33.1	12.4	32.8	36.9	37.0	13.4	13.2	12.7	2.3	2.4	2.5	+1.6	+4.6	+7.8	40.1
038	25.6	23.0	11.8	33.4	37.7	37.5	13.2	13.3	13.1	2.3	2.3	2.4	+2.0	+5.1	+8.2	41.2
	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓	⇓
Min	23.9	18.4	10.2	32.5	36.7	36.7	13.0	12.7	12.5	2.2	2.3	2.4	+1.2	+4.2	+7.4	39.4
Max	27.9	38.1	13.4	34.1	38.2	37.8	21.8	19.8	15.9	2.8	3.1	3.3	+2.9	+6.8	+8.2	41.4
Mean	26.0	27.3	12.0	33.0	37.2	37.2	13.7	13.4	13.1	2.4	2.4	2.6	+1.7	+4.9	+7.9	40.5
Std. Dev. σ_n	1.11	4.75	0.69	0.32	0.39	0.25	1.67	1.33	0.67	0.16	0.20	0.20	0.30	0.45	0.18	0.45

Note: Population Standard Deviation is used (σ_n), not sample standard deviation (σ_{n-1})

Appendix B. Performance of LNB I.F. Amplifier over –40 to +85 °C Temperature Range.

Temperature Test, BGA430 + BGB540 LNB IF Amp, PCB=430-051802 Rev B, -40 to +85 C

Overall Impression:

Good stability of DC operating point over temperature for both BGA430 and BGB540. No abnormal "peaking" or oscillatory behavior observed for BGA430 at –40 C. Input and Output match does deteriorate to worse than 10 dB return loss in some cases (see yellow highlights) but this issue could be remedied with component value tuning on PCB, etc.

Summary Of Data, Stand-Alone BGA430   (e.g. single – MMIC LNB IF Amp Solution)

Temperature	Frequency MHz	dB[s11]^2	dB[s21]^2	dB[s12]^2	dB[s22]^2	Current, mA
-40 C	950	12.1	33.3	>40	9.8	
-40 C	1450	9.4	33.5	40	8.9	22.5
-40 C	2150	8.5	29.3	40	13.0	
+25 C	950	17.7	32.7	>40	10.2	
+25 C	1450	19.2	32.5	>40	9.1	21.8
+25 C	2150	12.5	27.9	>40	13.2	
+85 C	950	16.7	32.2	>40	11.0	
+85 C	1450	17.8	31.5	>40	9.2	21.1
+85 C	2150	11.5	26.6	>40	13.3	

Summary Of Data, BGA430 + BGB540 --- Complete two MMIC IF Amp

Temperature	Frequency MHz	dB[s11]^2	dB[s21]^2	dB[s12]^2	dB[s22]^2	Current, mA
-40 C	950	25.2	33.7	>50	13.0	
-40 C	1450	14.0	37.8	>50	13.0	39.3
-40 C	2150	7.5	38.8	>50	12.0	
+25 C	950	21.8	32.3	>50	13.6	
+25 C	1450	29.9	36.4	>50	13.7	38.5
+25 C	2150	13.6	37.2	≈46	12.4	
+85 C	950	15.3	31.1	>50	14.3	
+85 C	1450	13.4	35.1	>50	15.7	37.7
+85 C	2150	12.7	35.4	>50	11.9	

Appendix C. Noise Figure Plot for Complete BGA430 + BGB540 LNB I.F. Amplifier.

Rohde and Schwarz FSEK3 V2.00   31 Jul 2002

BGA430+Pad+HPF+BGB540 Noise Figure

EUT Name: PCB=430-051802 RevB
Manufacturer: Infineon
Operating Conditions: V=5.0 V,I=40 mA, T=25 C
Operator Name: Gerard Wevers
Test Specification: Demo Board
Comment: LNB Application 950 - 1450 MHz
                     BGA430+3 dB PiPad + HPF + BGB540

Analyzer

RF Att: 0.00 dB   RBW :   1 MHz   Range: 50.00 dB
Ref Lvl: -40.00 dBm   VBW :   100 Hz   Ref Lvl auto: ON

Measurement

2nd stage corr: ON   Mode: Direct   ENR: HP346A.ENR
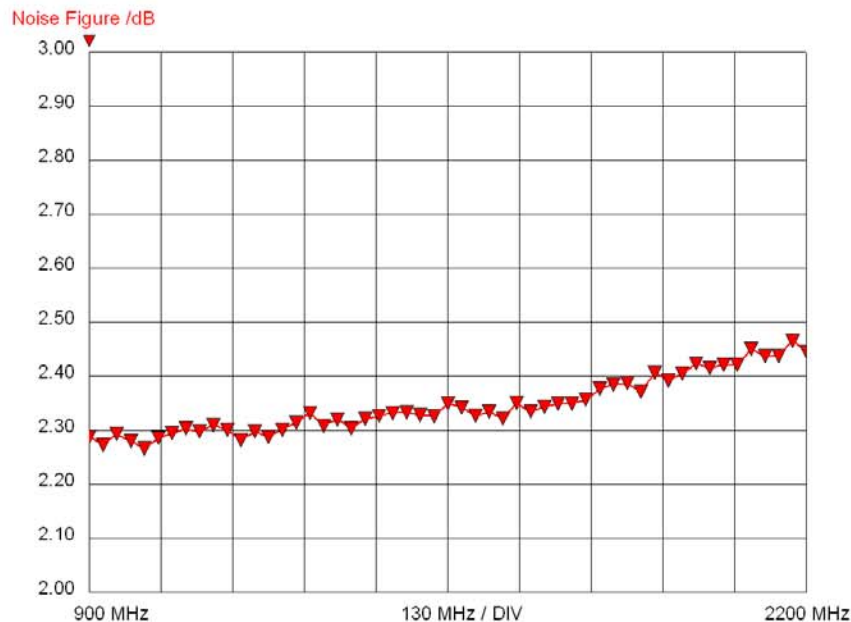
Appendix D. Revision Log

Revision Level	Date	Description of Modification(s)
A	24-July-2002	Initial Release
B	14-November-2002	First Revision • Addition of Temperature Test Data (Appendix B) • Revised System Block Diagram (Figure 3) • General text cleanup • Revised Schematic and Bill Of Materials
C	15-November-2002	Second Revision • General text cleanup
D	18-November-2002	Third Revision • Text Cleanup
E	19-November-2002	Fourth Revision • Text Cleanup