Direct Broadcast Satellite Systems

Application Note A009

NOTE: This publication is a reprint of a previously published Application Note and is for technical reference only. For more current information, see the following publications:

- AN1091, *1 and 2 Stage 10.7 to 12.7 GHz Amplifiers Using the ATF-36163 Low Noise PHEMT*, pub. number 5965-1235E.
- AN1136, *Low Cost Mixer for the 10.7 to 12.8 GHz Direct Broadcast Satellite Market*, pub. number 5966-2488E.
- AN1139, *950 to 2400 MHz IF Amplifier Using the INA-51063 and INA 54063*, pub. number 5966-3363.

Introduction

Direct Broadcast Satellite (DBS), as the name implies, provides a means of distributing television signals by broadcasting directly from a satellite to the end user. In a typical DBS system, the TV signal is received by a Low Noise Blockconverter (LNB), mounted at the focus of an antenna. The LNB down-converts the signal broadcast by the satellite to an Intermediate Frequency (IF), which in turn, is down-converted by a set-top converter to a signal on Channel 3 or 4 that can be decoded into picture and sound by a television set.

Two primary broadcast bands are currently in use: C band (at 4 GHz) and Ku band (at 12 GHz). C band systems (also referred to as Television Receive Only or TVRO) have been available for a number of years, but unfortunately require a large antenna dish (10' diameter or more) for reception. These systems lost a great deal of their popularity when television broadcasters began encrypting transmissions.

Alternative systems operate at Ku band, where the higher frequency allows the size of the antenna to be well below 1 meter. This application note describes devices that are available from Agilent Technologies and are appropriate for use in the expanding Ku band LNB market.

System Considerations

An LNB's most important specifications are noise figure (NF) and associated gain (G_A). The noise figure sets the sensitivity of the receiver, and determines how small of an antenna can be used with the LNB. For many systems, an LNB NF of 2.0 dB or less is quite adequate for viewers to receive a clear picture. However, esthetic considerations such as smaller antenna size, or geographic considerations such as fringe reception tend to cause LNBs with lower noise figure to be more attractive. Efforts to meet these ever decreasing noise figure demands have led to the development of technologies such as High Electron Mobility Transistors (HEMT). At present, LNB noise figures in the 1.2 to 1.5 dB range represent realistic system targets, with the expectation that market pressures will decrease this number still further in the future. The gain of the LNB ensures that sufficient power will be available to drive the set-top converter. The gain required from an LNB is typically between 50 and 65 dB, with 55 ±3 dB being a common specification.

The LNB can be thought of as consisting of four components: (1) Low Noise Amplifier (LNA), (2) mixer, (3) oscillator, and (4) IF amplifier. A typical block diagram is shown in Figure 1. The function and performance of each of these components will now be considered, along with a discussion of appropriate semiconductor devices for each that are offered by Agilent.

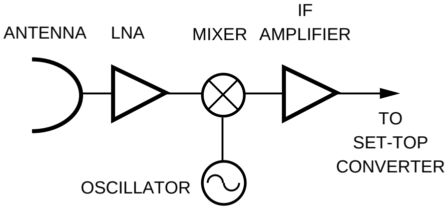

Figure 1. DBS Low Noise Block-Converter

LNA

The LNA is the "front end" of the block down-converter. It receives the broadcast television signal from the antenna, and with minimal signal-to-noise ratio degradation it amplifies the received signal sufficiently for further processing.

Required Specifications

Ku Band LNBs are most commonly designed to serve a specific satellite, which will be broadcasting in one of three frequency bands: 10.95 to 11.7 GHz, 11.7 to 12.2 GHz, or 12.25 to 12.75 GHz. Thus, the selected satellite sets the frequency band for the LNA. The most important electrical specifications of the LNA are the noise figure and the associated gain. The following cascade noise equation shows how these two parameters work together to establish the sensitivity of the LNB.

$$NF = NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2} + \dots \quad (1)$$

The noise figure of the first stage of the LNA sets an initial sensitivity level. The noise figure of each following stage degrades this sensitivity, but is mitigated by the preceding gain. The devices selected for the LNA must be capable of providing a somewhat lower noise figure than the LNB system requirement, and must provide sufficient gain to mask the noise contribution from the mixer and IF amplifier. If the mixer has a 7 dB noise figure, and its contribution to the cascade is to be negligible (< 0.05 dB), then at least 25 dB of gain is required in the LNA. This analysis leads to the following possible line-ups for the LNA.

Assuming a 10 dB NF for the mixer-IF amplifier cascade, an LNB NF of 1.5 dB can be obtained from a three stage cascade with the following devices:

stage 1: NF = 1.2 dB, G_A = 9 dB
stage 2: NF = 1.6 dB, G_A = 8 dB
stage 3: NF = 2.2 dB, G_A = 8 dB

A two stage cascade to yield the same result would require:

stage 1: NF = 1.3 dB, G_A = 12.5 dB
stage 2: NF = 2.1 dB, G_A = 12.5 dB

Devices

The stringent noise requirements derived in the previous section make it readily apparent that Gallium Arsenide (GaAs) is the appropriate technology for the LNA devices. While traditional MESFETs can provide adequate performance to achieve the three stage cascade, higher performance devices made with HEMT, PHEMT (Pseudomorphic High Electron Mobility Transistor), or InP (Indium Phosphide) technology are required for the two stage approach. Alternatively, the higher performance devices can be used to produce three stage cascades with NFs on the order of 1.0 dB.

FETs targeted for the DBS market are typically offered in a number of noise performance selections, with the cost of the FET decreasing as the noise figure increases. This allows the manufacturer to sell the entire distribution of product manufactured, keeping the cost low. It also makes sense from a systems perspective as (per the discussion of noise cascades, above) the latter stages of the LNA do not require premium noise performance. Thus the designer can select a line-up of devices that will provide the desired system performance at the most economical cost.

ATF-35 PHEMT Family

The highest performance FETs are manufactured using HEMT technology. A “sandwich” structure epitaxial material is used to create an electron gas of undoped gallium arsenide below the surface of the FET. The higher electron mobility resulting from this technique raises the f_T of the resulting structure, with consequent improvements in gain and noise figure performance. Agilent uses Pseudomorphic HEMT (PHEMT) technology, in which an indium layer is included in the sandwich structure to further improve mobility. The precise manufacturing techniques mandated by the extremely fine, high mobility device geometries also results in the bonus of improved product consistency.

Agilent offers the following PHEMT devices for use in Ku band LNAs.

ATF-35076:

200 µm PHEMT in ceramic 70 mil package with 0.8 dB NF,
10.0 dB G_A (premium first stage device).

ATF-35176:

200 µm PHEMT in ceramic 70 mil package with 0.9 dB NF,
10.0 dB G_A (average first stage device or premium second stage device)

ATF-35376:

200 µm PHEMT in ceramic 70 mil package with 1.2 dB NF,
9.5 dB G_A (average second stage device)

ATF-35576:

200 µm PHEMT in ceramic 70 mil package with 2.0 dB NF,
11.0 dB G_A (high gain third stage device)

Figure 2a shows a premium PHEMT line-up that achieves a cascade NF for the LNA of 0.9 dB with an associated gain of 31 dB. Figure 2b shows a “standard” PHEMT line-up that achieves a cascade NF of 1.0 dB for the LNA with an associated gain of 30.5 dB. A subtlety in the premium line-up is the selection of the ATF-35576 as the third stage in preference to the ATF-35376. This is because the system NF will be lowest if a high gain third stage device is used to buffer the mixer noise contribution in preference to a lower noise but lower gain third stage device.

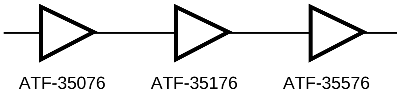

Figure 2a: Premium PHEMT LNA Line-up
NF = 0.9 dB; G_A = 31 dB

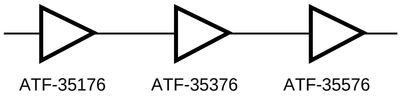

Figure 2b: Standard PHEMT LNA Line-up
NF = 1.03 dB; G_A = 30.5 dB

ATF-13 MESFET Family

Agilent also manufactures a line of MESFETs appropriate for use in DBS applications. MESFET are made using a relatively mature process that does not require the precision of MBE material or direct write of gates demanded by PHEMT devices. Thus, while the resulting FETs are lower performance, they are often more economical as well. MESFETs may be used to construct three stage DBS LNAs with noise figures in the 1.5 dB range, or used as economical second and third stage devices when coupled with a PHEMT front end.

Agilent offers the following MESFETs for use in Ku band LNAS.

ATF-13036:

250 µm MESFET in micro-X package with 1.1 dB NF,
9.5 dB G_A (premium 1st stage MESFET)

ATF-13136:

250 µm MESFET in micro-X package with 1.2 dB NF,
9.5 dB G_A (typical 1st stage MESFET)

ATF-13336:

250 µm MESFET in micro-X package with 1.4 dB NF,
9.0 dB G_A (2nd stage MESFET)

ATF-13736:

250 µm MESFET in micro-X package with 1.8 dB NF,
9.0 dB G_A (3rd stage MESFET, oscillator, active mixer)

ATF-13284:

250 µm MESFET in plastic package with 1.6 dB NF,
8.5 dB G_A (3rd or 4th stage MESFET; C band 2nd stage)

ATF-13484:

250 µm MESFET in plastic package with 2.0 dB NF,
7.5 dB G_A (4th stage MESFET; C band 2nd stage, oscillator, active mixer)

ATF-13170:

250 µm MESFET in hermetic gold package with 1.0 dB NF,
10.0 dB G_A (all stages, military or high-rel LNAs)

ATF-13100:

250 µm MESFET unpackaged chip with 1.1 dB NF,
9.5 dB G_A (all stages, hybrid assembly LNAs)

Designs based on these MESFETs should consist of three or four stages. The most common line-up is shown in Figure 3. An LNA using this cascade could provide an NF of 1.1 dB with 28 dB of associated gain.

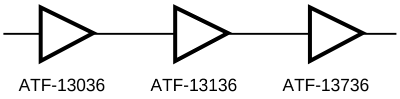

Figure 3. MESFET LNA Line-up
NF = 1.1 dB; G_A = 28 dB

Package Options

The selection of package style is a cost-performance tradeoff. In general, ceramic packages (micro-X or style 76) are the most cost effective choice for commercial systems. The higher performance style 70 gold package appears in systems where performance or screening considerations are more important than cost. The style 84 plastic package degrades gain sufficiently so that these devices are only appropriate for later stages in lower performance systems, in systems with unusually low mixer-IF noise figures, or in systems cascading four devices in front of the mixer. Chip versions are appropriate if a “chip-and-wire” hybrid construction approach is being used.

Circuits

The design of a 12 GHz LNA requires familiarity with proper microwave techniques, and is not a trivial task. The design proceeds from the S and noise parameters provided in the *Communications Components Designer’s Catalog* or on the data sheets. The impedance the circuit presents to the input of the FET will establish the noise performance, and should be as close to Γ_{opt} as possible across the band of interest. The impedance presented to the output of the FET must be $S_{22}'^*$ for maximum gain. Note that since FETs do not have perfect isolation, it is the output impedance as shifted by the generator impedance (S_{22}'), not the output impedance with the input loaded with 50 Ω (S_{22}) with which it must be matched.

Computer aided design is a virtual necessity. Common simulation programs include SuperCompact™ from Compact Engineering, MDS™ from Agilent Technologies, and Touchstone™ from EEsof. Circuit simulations should include major circuit parasitics, including via paths, major step discontinuities, and inductances associated with lumped elements. Since the S and noise parameter data is representative of a distribution of devices (typical variation is approximately ±10%), and since understandable circuit models are simplifications, and the simulation is not expected to be perfect. In general at least two iterations between simulation and physical circuit are required to generate a final working physical circuit.

Design techniques are the same whether working with PHEMTs or MESFETs. Of course, to realize the sub-one dB noise figures possible with PHEMTs requires focus on each potential tenth of a dB of loss in the circuit. The high performance of PHEMTs also means that the designer will need to pay special attention to out-of-band terminations. After all, these devices have the potential of working as amplifiers to frequencies above 18 GHz, and so must be correctly terminated at these frequencies! In general PHEMTs demonstrate an advantage in repeatability over MESFETs due to the higher-technology processing (e.g. MBE material, direct write of gates, etc.) they require.

The following circuit hints may help lead to a superior performing design.

1. BIAS. The DC operating point is a major factor in low noise performance. MESFET processing technology allows sufficient variation in pinchoff voltage and I_{dss} to make fixed resistor schemes impractical for setting a consistent bias point in volume production. Use an active bias circuit instead, such as the one described in application note AN-A002: *A 4 GHz TVRO LNA* (also shown schematically in Figure 4) to ensure consistent performance.

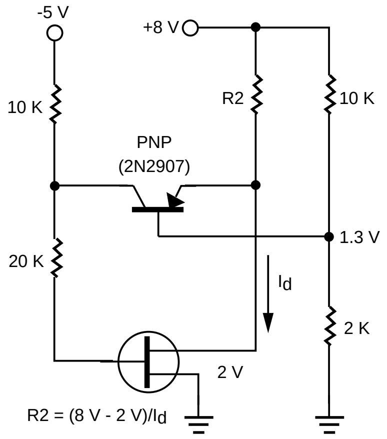

Figure 4. PNP Active Bias for FETs

2. CHOKE NETWORKS. Significant noise performance can be lost if the choke networks are not optimal. Choke networks should be “staged”, with a section nearest the RF circuitry providing decoupling at 12 GHz, and a second section nearer the power supply providing low frequency loading. For typical construction, the 12 GHz section is realized from a quarter-wave transmission line and a distributed area capacitor. Touching a large metal object, such as a pair of tweezers, to the area capacitor can be quite revealing. If the choke network is functioning properly, no change in performance will be seen. If noise figure changes, then the network is not providing adequate bypassing and should be improved by altering either the length of the transmission line or the area of the capacitor. Correcting a choke design can improve the noise performance of an amplifier by up to 0.5 dB.

3. MATCHING NETWORKS. All losses occurring in front of the first stage FET add directly to the LNA noise figure. The designer should take pains to eliminate as many of the losses as possible. Use high quality board material with consistent dielectric, such as PTFE. Select a circuit topology with a physically short input match. Avoid extremely thin input lines. Use a direct launch to the waveguide, eliminating the loss of an input connector. Eliminate the input blocking capacitor, or at a minimum use high-Q chip capacitors at self-resonance. Each of these can reduce the overall noise performance by a tenth of a dB.

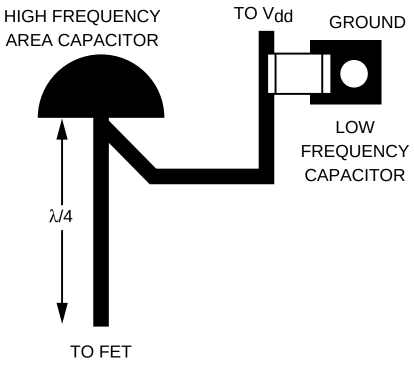

Figure 5. Staged Bias Choke Network

A single stage amplifier for the ATF-13136 employing many of these ideas is described in application note AN-G001: *ATF-13136 Demonstration Amplifier.*

Mixer

The mixer is the frequency converting element of the down-converter. It takes as inputs the signals coming from the LNA and the LO, and creates output signals at their sum ($f_{RF} + f_{LO}$) and difference ($f_{RF} - f_{LO}$) frequencies. The difference signal is then used to drive the IF amplifier.

Required Specifications

The most important specifications for the mixer are the frequency of operation, the noise figure, and the conversion loss (or gain). The mixer must be able to translate RF signals from the output of the LNA down to an IF frequency between 950 and 1750 MHz. The noise contribution of the mixer – IF amplifier cascade must be low enough not to effect the LNB sensitivity. Typically this translates to a NF of 10 dB or less. The amount of gain or loss in the mixer determines the number of stages required in the RF and IF to achieve a system gain of approximately 55 dB. Most systems are designed to cope with 7 dB of loss in the mixer. Spectral purity is typically not an issue in mixer selection as external filtering is employed.

Devices

The most popular approach is the use of matched Schottky Barrier diodes. The HSMS-8202 is a matched diode pair in the SOT-23 package making it suitable for surface mount applications. The design of a suitable mixer for DBS applications is covered in Agilent Application Note AN1052 (5091-4934E) and Agilent Application Note AN1136 (5966-2488E).

An alternate approach to the mixer is to use the gate of a GaAs FET as the frequency conversion element. Agilent has done some investigating of this approach. The topology selected used a MESFET in common source configuration. The RF signal was injected into the gate, which was matched for maximum power transfer at the RF frequency. The LO signal was injected into the drain. The IF was “picked off” the drain circuitry through an appropriate low frequency network incorporated in the choke network. The FET was operated at a “barely on” bias point (1 – 3 mA of I_{ds}.). The result was a mixer with typically 0 dB conversion loss and 4 to 5 dB noise figure. A schematic representation for the technique is given in Figure 6.

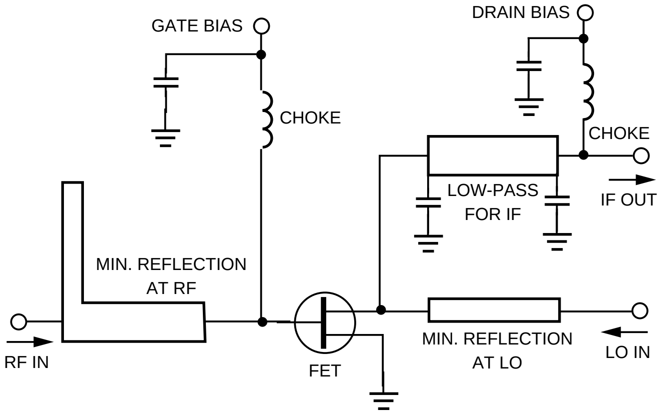

Figure 6. FET as Drain-Pumped Active Mixer

A major design consideration with this kind of mixer is repeatability; it is not unusual to have to re-tune the mixer from device to device. Active mixers may also exhibit significant amounts of gain ripple – sometimes 5 dB or more – over a 500 MHz bandwidth.

Engineers interested in pursuing this active mixer design should consider the following MESFETs:

ATF-13736
ATF-13484

Active mixers are covered in Agilent Application Note G005 (publication number 5091-3744E). Agilent also manufactures Gilbert-cell-based silicon MMIC mixers. However, these devices are not appropriate for Ku band LNB applications because of the RF frequency range and the high noise figure inherent in Gilbert-cell-based designs.

Oscillator

The oscillator provides the second signal needed by the mixer to down-convert the RF signal coming from the LNA to the IF frequency band.

Required Specifications

The primary oscillator specifications are frequency of oscillation, output power, and frequency stability. The appropriate oscillator frequency is determined by which satellite is being received, and will be 950 MHz lower than the low end of the satellite broadcast band. Thus for satellites broadcasting at 10.95 to 11.7 GHz, the LO frequency will be 10.0 GHz; for 11.7 to 12.2 GHz satellites the LO will be 10.75 GHz, etc. The output power needed will be a function of the mixer, but is typically in the +4 to +8 dBm range. Frequency stability is a major concern; a typical requirement for the overall frequency stability of the oscillator would be +3 MHz maximum over a -20 to +60°C temperature range. This translates into a typical pushing figure (frequency variation with bias) on the order of 2 MHz per volt, and a typical pulling figure (frequency variation with impedance) of 1 MHz maximum into a 1.5:1 VSWR. In general, phase noise is a less important specification, with performance on the order of -55 to -60 dBc/Hz @ 10 kHz being adequate.

Devices

The most common device for Ku band oscillator use is an inexpensive GaAs FET. In general, a lower performance (lower gain) device is preferred, as it is less prone to the generation of spurious oscillation modes. Appropriate choices from Agilent include the ATF-25 and -26 series of general purpose FETs and the ATF-10 and -13 series of low noise FETs. Plastic packaged devices are particularly suitable because of their low price and lower gain. Available devices include:

ATF-26884:
250 µm general purpose MESFET in plastic package

ATF-13484:
250 µm low noise MESFET in plastic package

The ATF-13484 has a slight edge in performance for the oscillator application in that it has approximately 10 dB lower phase noise.

Occasionally economies of scale suggest using the same FET for both the final stage of the LNA and for the oscillator. When this approach is taken, the oscillator FET typically becomes:

ATF-13736:
250 µm MESFET in micro-X package with 1.8 dB NF,
9.0 dB G_A

Circuits

An appropriate method for designing oscillators from S parameter data is described in application note AN-A008: *Oscillator Design*. The selected topology should provide a high Q resonator and freedom from spurious modes of oscillation. One topology that Agilent has found to be effective is the shunt feedback, dielectrically stabilized design shown in Figure 7.

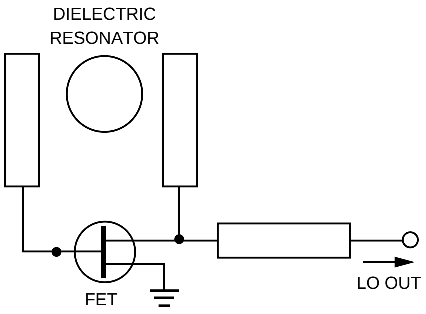

Figure 7. Parallel Feedback DRO

Points to consider for the oscillator design:

1. RESONATOR SELECTION. The use of a dielectric puck as the resonator ensures a high Q oscillator and allows temperature compensation through the selection of the temperature coefficient of the puck. Pucks are, however, sensitive to acoustical excitation, and must be mounted in rigid housings to prevent microphonics. Mounting the puck directly on the case wall (i.e., cutting away the PC board under the puck) can avoid problems associated with the change in dielectric that many board materials exhibit when operated at over temperature.

2. TOPOLOGY. Power should be taken from the drain terminal, as this results in maximum output power, often making it possible to include resistive padding between oscillator and mixer to further reduce pulling. Although adequate power can sometimes be drawn from the source terminal, it is typically 5 dB lower than what is obtainable from the drain. The gate terminal cannot reliably provide the required output power, so topologies using the gate as the output should be avoided.

   Either series or shunt designs are possible. Shunt designs have exhibited fewer spurious modes. With either type of design, the transmission lines in the resonator should be terminated in 50 Ω to provide out-of-band loading and prevent spurious oscillations. A good test of the design is to apply bias to the oscillator with the puck (or resonator) removed – no oscillations should occur.

3. BIAS. The most common bias scheme is to bias the FET at I_{dss} (ground both gate and source). When the oscillation starts, the bias will typically jump to a current of approximately 2/3 I_{dss}. Choke schemes on the drain should be the same as used for amplifier designs.

IF Amplifier

The role of the IF amplifier is to provide the output signal from the LNB. It must take the downconverted signal from the output of the mixer and amplify it sufficiently to provide a signal to drive the set-top converter.

Required Specifications

The primary specifications for the IF amplifier are bandwidth, gain, and output power. The bandwidth is a relatively fixed 950 to 1750 MHz (although some designers prefer to specify 950 to 2000 MHz to add margin and reduce roll-off versus frequency). The IF amplifier will be used to make up the balance of the gain needed after the contributions of the LNA and mixer are considered. Because of the lower frequency of operation, IF stages are usually the most economical place to add extra gain. In a typical system the LNA provides 30 dB of gain and the mixer has 7 dB of loss, so the IF amplifier must provide 32 dB of gain if the LNB is to have 55 dB of overall gain. The output power of the IF amplifier must be sufficient to drive the set-top converter through a moderate length of lossy coax; typically +3 to +8 dBm of power is required.

The LNB must also exhibit flat gain within each television channel; typically <0.1 dB ripple per 5.5 MHz (single channel bandwidth) is required. Gain equalizers may be used with the IF amplifier to provide a “negative gain slope” (i.e., more gain at higher than lower frequencies), so that the cascade of the IF amplifier with the remaining LNB circuitry has a flat gain versus frequency response.

Devices

The IF amplifier is most commonly designed using gain block MMICs (Monolithic Microwave Integrated Circuits). MMICs offer the advantages of ease of use and small size. Discrete devices can also be used if substantially more design effort is invested. Silicon is the technology of preference, as it is significantly more economical than GaAs.

Agilent offers two lines of MMICs appropriate for IF amplifier use: MSA products and INA products. The MSA lineof MODAMP™ MMICs are single-stage Darlington-based resistive feedback amplifiers. The most popular MSA series products for DBS IF amplifier use are:

MSA-0886:

15 dB gain, +10 dBm P_{1dB} at 8 V, 35 mA in 85 mil surface mount plastic package.

MSA-0686:

12 dB gain, +1 dbm P_{1dB} at 3.5 V, 16 mA or +9 dBm at 4 V, 30 mA in 85 mil surface mount plastic package.

For good bias stability over temperature, MSA devices require current source biasing. This can be simply accomplished by biasing through a collector resistor. If this scheme is used the power supply requirement for the IF amplifier is at least 2 volts greater than the device voltage of the MSA amplifier. If a PNP current source bias is used (see AN-S003 in the *Communications Components Designer's Catalog*), the power supply requirement can be reduced to 1 volt above the device voltage of the MSA.

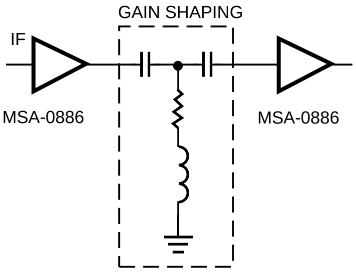

Figure 8. IF Amplifier using MSA-0886

The most common IF amplifier configuration is a cascade of two devices, with some gain flattening used in the inter-stage. Systems requiring more gain from the IF amplifier may also use a cascade of three devices.

The INA line of MagIC™ low noise MMICs are two stage amplifiers with higher gain, lower noise figure, better isolation, and better bias stability over temperature than MSA MMICs. Unlike MSA amplifiers, INA devices can be operated as voltage-controlled amplifiers, i.e., no "headroom" is required between the INA device voltage and the power supply voltage. The most popular INA series products for DBS IF amplifier use are:

INA-10386:

25 dB gain, +10 dBm P_{1dB} at 6 V, 45 mA, in 85 mil surface mount plastic package.

INA-03184:

25 dB gain, 0 dBm P_{1dB} at 4 V, 10 mA, in 85 plastic package.

The INA-10386 is the most common choice for use in the IF amplifier application. The INA-03184 offers the advantages of flatter gain to 2 GHz, and lower bias current. It has the disadvantages of significantly lower output power (-2 dBm vs. +10 dBm) and greater sensitivity to ground parasitics. This sensitivity precludes the offering of this product in a surface mount package. The additional lead inductance causes instability, so a hole must be placed in the PC board to mount this device.

Common IF amplifiers use either a single INA device, or a cascade of one INA and one MSA. High gain systems may cascade two INAs. Some standard combinations of MSAs and INAs are shown in Figure 9.

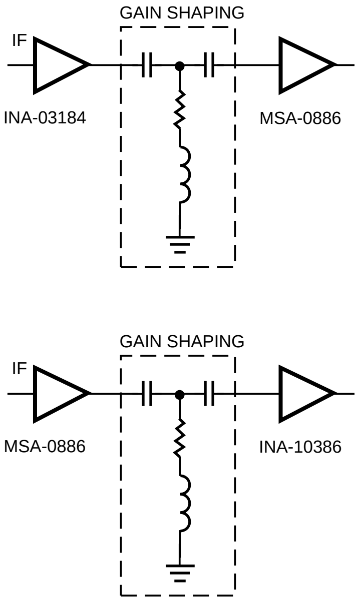

Figure 9. IF Amplifiers using INA MMICs

Discrete silicon bipolar transistors may also be used to create an IF amplifier, but require design time investment. Agilent offers two product lines of discrete bipolar devices appropriate for use in the IF stage. The AT-414 based product has the best gain and noise figure; the AT-00511 is the most economical.

Transistors offered include:

AT-41411:

4 µm pitch transistor with 1 GHz Maximum Stable Gain (MSG) of 23 dB in industry standard SOT-143 plastic surface-mount package.

AT-41486:

4 µm pitch transistor with 1 GHz MSG of 24 dB in 85 mil plastic surface mount package with superior electrical and thermal performance.

AT-00511:

10 µm pitch transistor with 1 GHz MSG of 18 dB in industry standard SOT-143 plastic surface mount package.

Circuits

MMICs offer the advantages of small size and ease of use. Circuits consist of 50 Ω lines, blocking capacitors, and bias circuitry, so no design time is required unless equalization is incorporated between MMIC stages. Inexpensive PC boards such as epoxy-glass are appropriate.

For biasing, MSA MMICs require the use of a current source. This is typically accomplished by dropping at least two volts across a resistor. The temperature coefficient of the resistor can be selected to provide additional gain compensation over temperature. If the impedance of the bias resistor is at least 400 Ω, no additional bias chokes are required. More information on general MODAMP MMIC circuitry can be found in application notes AN-S001: *Basic MODAMP MMIC Circuit Techniques* and AN-S003: *Biasing MODAMP MMICs*. An IF amplifier using a cascade of two MSA-0886 devices with gain equalization is given in AN-A007: *4 GHz Television Receive Only LNB Design*.

The circuit requirements for INA MMICs are very similar to those for MODAMP MMICs. The most significant difference is the greater sensitivity to grounding parasitics, necessitating excellent grounding and the use of thin (<1/32") PC boards for proper operation. INA MMICs also have the advantage that they can be biased from voltage sources as well as current sources, allowing operation from lower voltage power supplies. More information on INA circuits can be found in application note AN-S012: *MagIC™ Low Noise Amplifiers*.

When designing the IF amplifier with discrete transistors, general gain stage transistors should be used. Each stage should provide 10 to 15 dB of gain. The wide percentage bandwidth suggests the use of resistive feedback stages; usually a cascade of three to four devices is required. The low frequency of operation allows the use of inexpensive PC boards such as epoxy-glass boards.

A discrete transistor design must include bias circuitry that establishes a stable operating point over temperature. A resistor network incorporating a collector stabilization resistor is a common solution; alternatively an active bias circuit with PNP transistors can be used. Most discrete transistors are designed for optimum performance at V_{CE} = 8 V, but can be used with reasonable results at bias levels as low as 3 V. Thus discrete designs allow the engineer some flexibility in supply voltages.

Putting the System Together

While it is beyond the scope of this note to develop a complete LNB in detail, there are a few comments about the integration of the components discussed above that are appropriate to make.

1. FILTERING. Most LNBs require the use of an image reject filter, which should be located in front of the mixer. No amplification should be done between the filter and the mixer, as amplification would introduce additional image noise.

2. GAIN SHAPING. Gain shaping is most appropriately accomplished after the mixer and between the IF stages, where it doesn't interfere with noise figure and where gain and power are "cheap." Passive sloping networks such as frequency-bypassed attenuators or shunt RL networks are good choices.

3. CAVITY EFFECTS. The cavity in which the LNB sits must be designed so that the dimensions do not form a resonant cavity. Occasionally, RF absorptive material such as Echosorb™ will be used to damp cavity resonances. Ground walls and via lines should be used to partition the circuitry so that no more than 30 to 40 dB of gain is present in a single enclosure. Raised circuit elements such as molded chokes and wire inductors that can act as antennas should be kept to a minimum. The oscillator circuit should be in a separate enclosure from the rest of the circuit.

4. BIAS LINES. Care must be taken to avoid cross-talk through the bias lines. Good bypassing and isolated bias feeds are essential.

Conclusions

Agilent has a commitment to the DBS market. This commitment is reflected in the wide range of products offered to support this market. This commitment is also reflected in a history of volume production of both silicon and gallium arsenide devices used in DBS LNBs.

Designers following the guidelines outlined above should find themselves successful participants in this expanding market place. As technology advances, expect more offerings and even better performance in future products offered for DBS use.

Agilent Technologies
Innovating the HP Way

www.semiconductor.agilent.com

Data subject to change.

Obsoletes 5091-8819E
5968-3629E (11/99)