APN-003 Rev 3 August 15, 2007

RF Equipment Selection and Installation

Overview

NovAtel offers GPS antennas and cables tailored for use with the OEM4, OEMV, and SSII families of GPS receivers. These accessories provide for both easy installation and optimal operation. However, as the receivers are designed to meet the needs of a wide range of applications, the use of non-NovAtel accessories or a unique installation may be desired. This application note provides information on the standard NovAtel configuration, as well as recommendations for meeting the receiver's RF input requirements in special cases. In addition, information on obtaining the equipment required for such cases is given.

Legend

A variety of symbols are used in this application note to depict equipment configurations and characteristics. The meaning of each symbol is given below.

Table 1 – Legend

Symbol	Description
—≪ or ≫—	A connection between two pieces of equipment, either directly or through an adapter.
⊣⊢	Circuitry that blocks DC power but allows RF signals to pass.
ξ	Circuitry that allows DC power to pass but blocks RF signals.
—∽—	Current-limiting circuitry, such as a fuse.

1 Receiver Requirements

NovAtel's OEM4, OEMV and SSII families of GPS receivers support an RF input signal range of +15 dB to +35 dB, with +20 dB being an ideal nominal target, and the example used throughout this application note.

NovAtel sells a variety of RF cables ranging in length from 8.5 cm to 30 meters. The following table shows the typical signal power loss of these RF cables in dB:

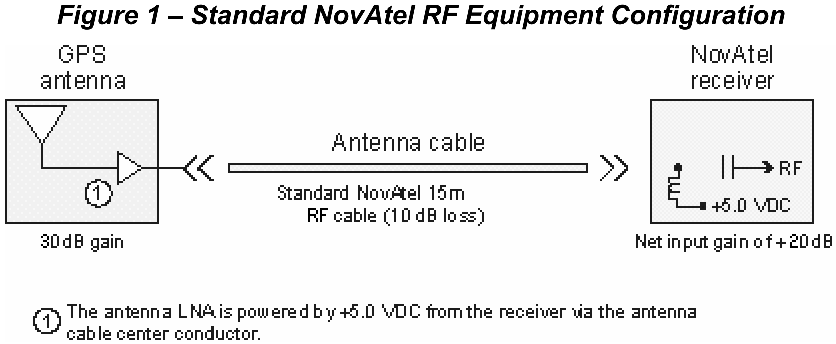
Table 2 – NovAtel RF Cable Loss Figures

RF Cable Part Number	L1 (1575.42 MHz)	L2 (1227.60 MHz)
01017278 8.5 cm MMCX to TNC	-0.29 dB	-0.28 dB
01016772 22.5 cm MMCX to TNC	-0.35 dB	-0.32 dB
GPS-C006 5 m TNC to TNC	-3.28 dB	-2.85 dB
GPS-C016 15 m TNC to TNC	-10.2 dB	-8.80 dB
GPS-C032 30 m plus TNC pigtail cables	-11.3 dB	-10.3 dB

2 Standard Installation using NovAtel Equipment

Using NovAtel's GPS antennas and coaxial cables, the GPS receiver's requirement for +15 dB to +35 dB gain from the antenna, including the antenna element, LNA and cable at its RF input is easily met. All NovAtel GPS antennas employ a built-in, low-noise amplifier (LNA), which typically provides +25 to +35 dB of gain to the GPS satellite signal. The power to the antenna LNA is provided through the center conductor of the receiver's RF port. *Figure 1* shows a standard antenna cable configuration using NovAtel's 15 meter, ~10 dB loss RF cable and a GPS antenna with a +30 dB gain LNA.

Figure 1 – Standard NovAtel RF Equipment Configuration



3 Special Cases

For a specialized application or custom installation, GPS antennas and coaxial cables other than those offered by NovAtel may be preferred. In these cases, extra care must be taken to ensure the RF equipment being used meets the receiver's RF input signal range requirements. The sections that follow provide recommendations for special cases that may occur with the use of non-NovAtel accessories, as highlighted in *Table* 3.

Table 3 – Special Cases

Case	Related Section
The combined gain of the RF equipment is lower than 15 dB: $\mathtt{GAIN}_{\mathtt{ANTENNA}} - \mathtt{LOSS}_{\mathtt{CABLE}} - \mathtt{LOSS}_{\mathtt{OTHER}} < 15\ \mathtt{dB}$	*Section 3.1, Low Input Gain* below
The combined gain of the RF equipment is higher than 35 dB: $\mathtt{GAIN}_{\mathtt{ANTENNA}} - \mathtt{LOSS}_{\mathtt{CABLE}} - \mathtt{LOSS}_{\mathtt{OTHER}} > 35\ \mathtt{dB}$	*Section 3.2, High Input Gain* on page 7
The combined current draw of the RF equipment is higher than 100 mA: $\mathtt{I}_{\mathtt{ANTENNA}} + \mathtt{I}_{\mathtt{OTHER}} > 100\ \mathtt{mA}$	*Section 3.3, Insufficient Current Available* on page 8
The antenna requires an input voltage other than +5.0 VDC.	*Section 3.4, Different Voltage Required* on page 8
A single antenna must supply a GPS RF signal to multiple receivers.	*Section 3.5, Single Antenna Supplying Multiple Receivers* on page 9
The cables available are not long enough.	*Section 3.6, Insufficient Cable Length* on page 11

3.1 Low Input Gain

If the cable loss reduces the LNA gain provided by the selected antenna to less than 15 dB, a low-noise amplifier must be added "in-line" between the antenna and the receiver. The in-line amplifier must provide sufficient gain to ensure the RF input signal to the receiver is provided within the range of +15 dB to +35 dB, with +20 dB being a good target for which to aim. The in-line amplifier should be installed as close to the GPS antenna as possible to ensure the GPS signal is amplified when the signal to noise ratio is at its highest. Depending on the power requirements of the amplifier, the configuration of the RF equipment will vary, as shown in *Table 4*.

Table 4 – Solutions for Low Input Gain based on RF Equipment Power Requirements

<table>
<tr><th>Input Voltage</th><th>Total Current Draw
(See Section 3.1.1)</th><th>Solution</th><th>Additional Equipment Required</th></tr>
<tr><td rowspan="2">The antenna LNA and in-line amplifier both accept +5.0 VDC.</td><td>< 100 mA</td><td>Connect the in-line amplifier directly to the receiver, as shown in Section 3.1.3.1 on page 5.</td><td>• In-line amplifier</td></tr>
<tr><td>> 100 mA</td><td>Add a power supply for the in-line amplifier and a bias-T to inject the supply in the RF line, as shown in Section 3.1.3.2 on page 5.</td><td>• In-line amplifier
• External power supply
• Bias-T</td></tr>
<tr><td rowspan="2">Both the antenna LNA and the in-line amplifier require a supply voltage other than +5.0 VDC but they both accept the same input voltage.</td><td>< 100 mA</td><td>Connect the in-line amplifier directly to the receiver, as shown in Section 3.1.3.1 on page 5, and connect an external power supply through the receiver, as shown in Section 3.4 on page 8. This solution is valid only for the OEM4-G2, OEM4, Euro4, OEMV-1, OEMV-3, and SSII GPS cards. Use the solution provided in Section 3.1.3.2 on page 5 for other receivers.</td><td>• In-line amplifier
• External power supply
• SSII = 40 mA max
• OEMx = 100 mA max</td></tr>
<tr><td>> 100 mA</td><td>Add a power supply and a bias-T to inject the supply in the RF line, as shown in Section 3.1.3.2 on page 5.</td><td>• In-line amplifier
• External power supply
• Bias-T</td></tr>
<tr><td>The antenna LNA and in-line amplifier require different input voltages.</td><td>Any</td><td>Add a power supply for the in-line amplifier, a supply for the antenna, and a bias-T, as shown in Section 3.1.3.3 on page 6.</td><td>• In-line amplifier
• External power supply
• Bias-T</td></tr>
</table>

3.1.1 Current Requirement

As shown in *Table 4*, the total amount of current required by the in-line amplifier and the GPS antenna LNA is a factor when determining how to set up the RF equipment. Most NovAtel OEM4, OEMV, and SSII family GPS receivers can provide up to 100 mA at +5.0 VDC on the center conductor of the RF port, although there are a few exceptions; please refer to sections 3.3 and 3.4 of this document for more detail about this. Therefore, if the combined current draw of all the RF equipment connected to the port, including the in-line amplifier, is less than 100 mA, the receiver can supply the power.

For example, if the selected antenna's LNA requires 50 mA and there is no other equipment between the antenna and the receiver that draws current, an in-line amplifier that draws 10 mA can be used without the addition of an external supply. An exception is the SSII, which can only source 40 mA maximum instead of 100 mA.

3.1.2 *Amplification Requirement*

Select an in-line amplifier that increases the signal gain by the amount necessary to result in an overall gain of +20 dB, as shown in the formula below. Be sure to take into account the loss created by any additional equipment being used with the in-line amplifier, such as bias-Ts.

$$\text{AMPLIFICATION} = 20\ \text{dB} + \text{LOSS}_{\text{CABLE}} + \text{LOSS}_{\text{OTHER}} - \text{GAIN}_{\text{ANTENNA}}$$

For example, if the selected antenna LNA provides +30 dB gain and the cable has a loss of -20 dB, then +10 dB amplification must be added.

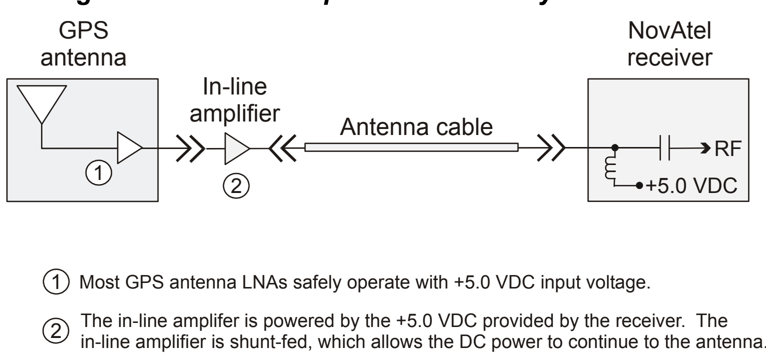
3.1.3 *Solutions*

As discussed previously, the installation of the in-line amplifier depends upon its power requirements. The sections that follow describe the various installation solutions as previously highlighted in *Table 4*. See *Section 4* on page 13 for more information on suppliers of in-line amplifiers and bias-Ts.

3.1.3.1 *In-Line Amplifier Powered by the Receiver*

If the RF equipment draws a total of less than 100 mA, as described in *Section 3.1.1* on page 4, the antenna LNA and in-line amplifier both accept a +5.0 VDC supply, and the inline amplifier is capable of passing the DC power from the receiver, then the equipment can be connected directly to the receiver without the need for an external power supply. *Figure 2* illustrates this configuration.

Figure 2 – In-Line Amplifier Powered by the Receiver

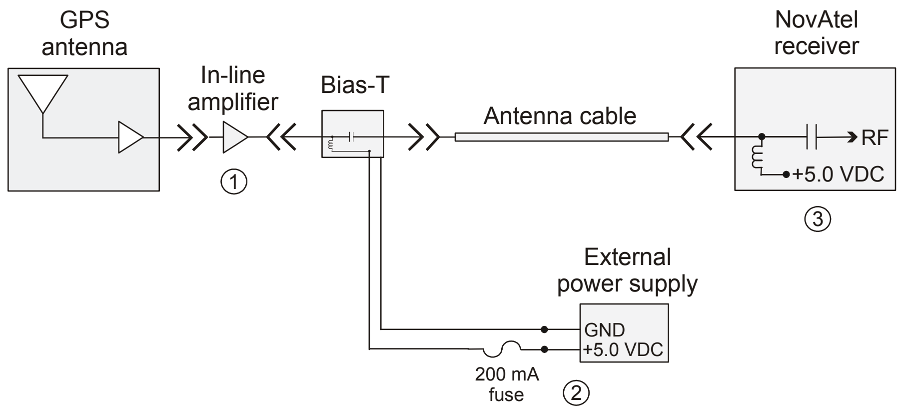


3.1.3.2 *In-Line Amplifier Powered from an External Power Supply*

Figure 3 illustrates an in-line amplifier that requires an external power source because the 100 mA provided by the receiver is not enough current. The in-line amplifier is powered directly via the bias-T and coaxial cable, with the DC power continuing on to the GPS antenna LNA. The bias-T should include circuitry to prevent DC power from being fed back to the receiver and the

ANTENNAPOWER OFF command[1] must be issued to disable the GPS receiver's internal LNA power supply[2].

Figure 3 – In-Line Amplifier Powered by an External Supply



① The in-line amplifier operates from power supplied via the coaxial cable center conductor and is shunt-fed, which allows the DC power to continue down the coaxial line to the antenna.

② The fusing and power supply requirements depend on the in-line amplifier and antenna. 200 mA and +5.0 VDC are examples shown for illustration purposes only.

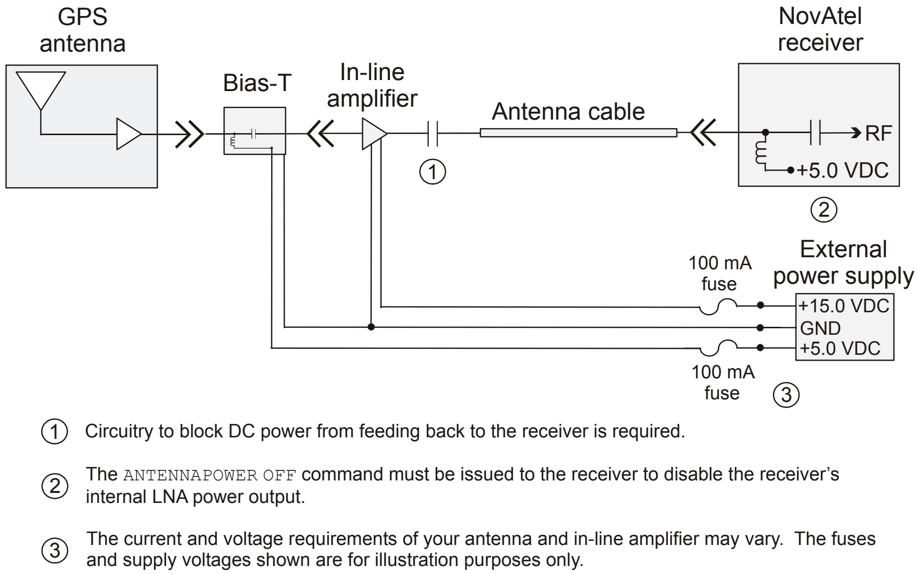
③ The ANTENNAPOWER OFF command must be issued to the receiver to disable the receiver's internal LNA power output.

3.1.3.3 In-Line Amplifier and Antenna Powered by Separate Supplies

Figure 4 illustrates a more complicated solution using an in-line amplifier that requires a power source that differs from that required by the antenna. The bias-T should include circuitry to prevent DC power from being fed back and the ANTENNAPOWER OFF command[1] must be issued to disable the receiver's internal LNA power supply. Since the bias-T is not placed between the in-line amplifier and the receiver, DC blocking circuitry must be added between the two[2]

[1] The ANTENNAPOWER command is not valid for OEMV-1, SSII and V1/SSII based FlexPaks. For OEMV1 and SSII, remove the DC power input on pin #1 to disable antenna power. Antenna power cannot be disabled on FlexPak enclosures.
[2] Proper fusing or current limiting should be incorporated in the external power supply line.

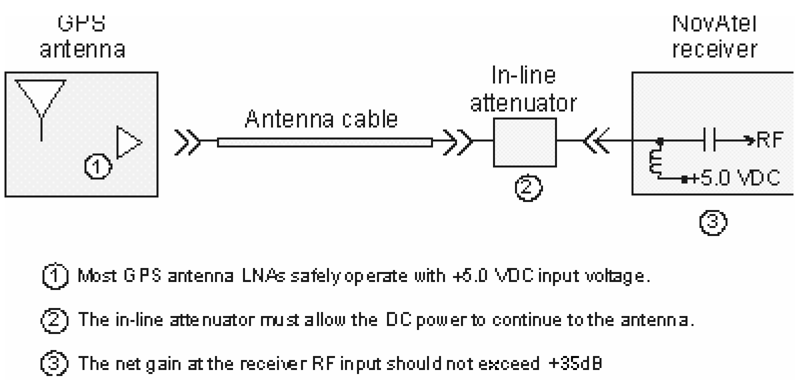
Figure 4 – In-Line Amplifier and Antenna Powered by Separate Supplies



3.2 High Input Gain

If the antenna LNA gain exceeds the cable loss by more than +35 dB, the RF signal must be attenuated before reaching the receiver, as shown in *Figure 5*.

Figure 5 – In-Line Attenuator



3.2.1 Attenuation Requirement

In this example, we will select an in-line attenuator that reduces the signal by the amount necessary to result in an overall gain of +20 dB, as shown in the formula below. Be sure to take into account the loss created by any additional equipment being used with the attenuator. Install the attenuator as close to the receiver as possible to avoid adding extra noise to the GPS signal.

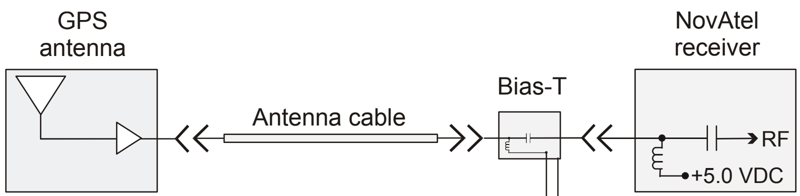
$$\mathrm{ATTENUATION} = \mathrm{GAIN}_{\mathrm{ANTENNA}} - \mathrm{LOSS}_{\mathrm{CABLE}} - \mathrm{LOSS}_{\mathrm{OTHER}} - 20\ \mathrm{dB}$$

For example, if the selected antenna LNA provides +40 dB gain and the cable has a loss of -10 dB, a -10 dB attenuator can be added. See *Section 4* on page 13 for more information on in-line attenuator suppliers.

3.3 Insufficient Current Available

Most NovAtel OEM4 and OEMV family receivers provide up to 100 mA from their RF ports; two exceptions are the OEMV-1 and SSII GPS cards, which provide no LNA power unless external power is applied to pin#1 (see section 3.4 for more detail). If the OEMV-1 or SSII is housed within the FlexPak enclosure, pin#1 is already connected to external power inside the FlexPak, and so the TNC connector on the FlexPak-V1 or FlexPak-SSII will have +5.0 VDC LNA power output on the center conductor by default; the FlexPak-V1 can source up to 100 mA, and the FlexPak-SSII can source up to 40 mA. In cases where the RF equipment connected to the RF port consumes more than this amount, an external power supply and bias-T must be added to the installation. The bias-T should include circuitry to prevent DC power from being fed back to the receiver and the `ANTENNAPOWER OFF` command must be issued to disable the receiver's internal LNA power supply. A simple installation with an antenna LNA that requires more than 100 mA is shown in *Figure 6*:

Figure 6 – External Power Supply to Meet Current Requirements

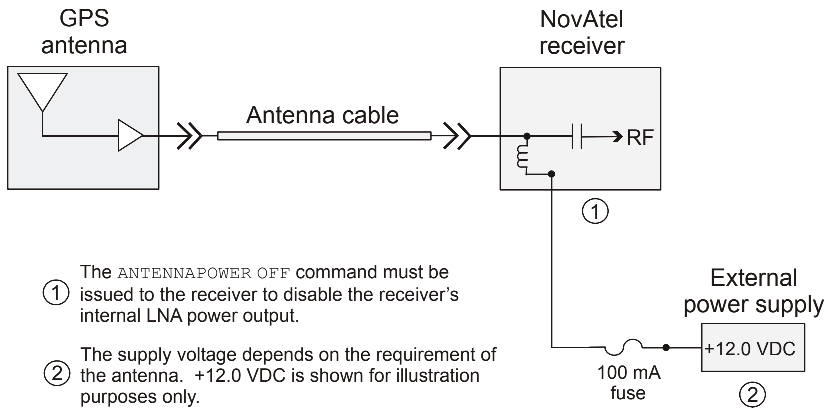


1. The `ANTENNAPOWER OFF` command must be issued to the receiver to disable the receiver's internal LNA power output.
2. The current and voltage requirements of your RF equipment may vary. The 200 mA fuse and +5.0 VDC supply are for illustration purposes only.

3.4 Different Voltage Required (OEM4-G2, OEM4, Euro4, OEMV-1, OEMV-3, and SSII Only)

By default, all OEM4 and OEMV (except OEMV-1 and SSII) family receivers output +5.0 VDC and up to 100 mA on the center conductor of their RF port to supply power to an active antenna LNA. If the receiver is an OEM4-G2, OEM4, Euro4, OEMV-1, OEMV-3, or SSII GPSCard, a convenient method for supplying the antenna with a different voltage is available. By using the external LNA power input pin and the ANTENNAPOWER command, an external source can be used to power the antenna LNA via the receiver, as shown in *Figure 7*. However, this method is acceptable only if the current draw of the RF equipment is less than 100 mA. If this is not the case or if the receiver is not an OEM4-G2, OEM4, Euro4, OEMV1, OEMV-3, or SSII the configuration described in *Section 3.3* must be used[2].

Figure 7 – Antenna Powered through the Receiver by External Supply



To create this configuration, first connect an external DC power source to the LNA power input pin. The pin number and voltage requirements for the external LNA power input are given in *Table 5* for each receiver type[3].

Table 5 – External LNA Power for GPSCards

Receiver	External LNA Power Input Pin	Voltage Input Range	Current Available from the RF port
OEM4-G2	40	+12 to +30 VDC	100 mA
OEM4-G2L	Not Available	n/a	n/a
OEM4	40	+12 to +30 VDC	100 mA
Euro4	B4	+12 to +30 VDC	100 mA
OEMV-1	1	+5.5 to +16 VDC	100 mA
OEMV-2	Not Available	n/a	n/a
OEMV-3	40	+5.5 to +18 VDC	100 mA
SSII	1	+5.0 to +18 VDC	40 mA

Then, issue the `ANTENNAPOWER OFF` command[4] to the receiver to disable the receiver's RF port power output. The externally supplied power will now be available at the receiver's RF port to power the antenna.

3.5 Single Antenna Supplying Multiple Receivers

If a single antenna is to be connected to multiple receivers, a splitter must be inserted between the antenna and the receivers. *Figure 8* illustrates a typical setup using a splitter to provide two receivers with the GPS signal. The splitter is designed so that one of the receivers provides power to the antenna while the other is blocked so no DC power passes from it to the antenna or back to the first receiver.

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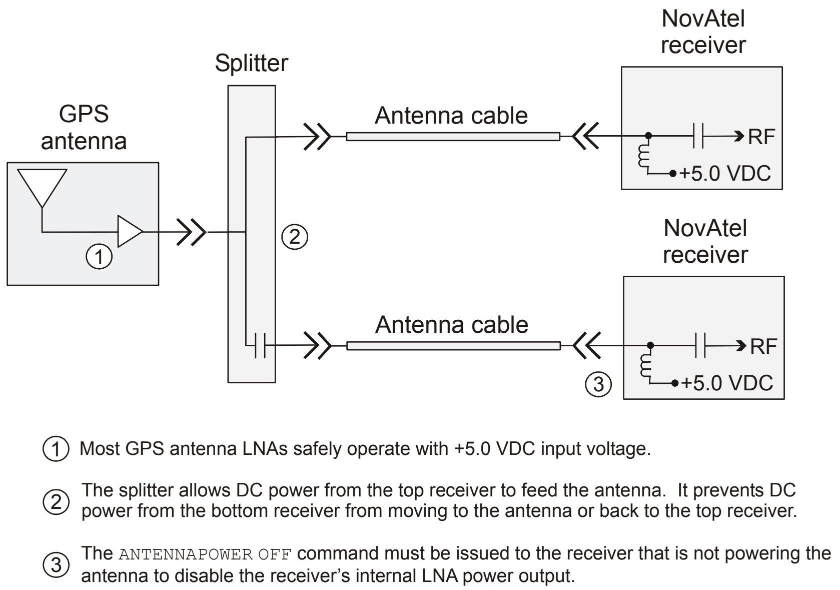
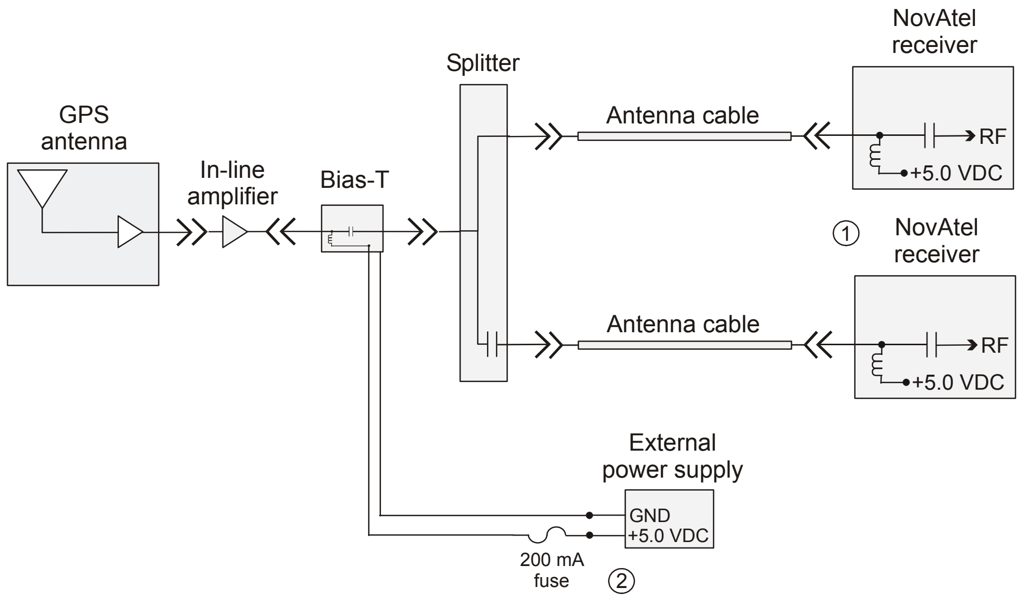
[3] This option is not available on OEM4-G2L or OEMV-2 GPS receivers.
[4] The ANTENNAPOWER command is not valid for OEMV-1, SSII and V1/SSII based FlexPaks. For OEMV1 and SSII, remove the DC power input on pin #1 to disable antenna power. Antenna power cannot be disabled on FlexPak enclosures.

Figure 8 – Single Antenna to Multiple Receivers



If the overall gain at the receiver is less than +15 dB due to the addition of the splitter and any other equipment introduced, an in-line amplifier must be installed between the antenna LNA and the splitter, where the signal to noise ratio is at its highest. For example, if the antenna provides +30 dB of gain, the connection between the antenna and the splitter introduces -5 dB loss, the splitter adds -5 dB loss and the cable between the splitter and receiver reduces the signal by -10 dB, amplification by at least +5 dB is required to yield the minimum input gain requirement of +15 dB; to attain a net RF input gain of +20 dB, then +10 dB of amplification would be required. *Figure 9* shows an in-line amplifier requiring an external supply and, therefore, a bias-T. The bias-T should include circuitry to prevent DC power from being fed back to the receiver and the `ANTENNAPOWER OFF` command must be issued to disable the receiver's internal LNA power supply. See *Section 3.1* starting on page 3 for other installation solutions based on the power requirements of the in-line amplifier.

Figure 9 – Single Antenna to Multiple Receivers with In-Line Amplifier



1. The ANTENNAPOWER OFF command must be issued to each of receivers to disable their internal LNA power outputs.
2. The fusing and power supply requirements depend on the in-line amplifer and antenna. 200 mA and +5.0 VDC are examples shown for illustration purposes only.

3.6 Insufficient Cable Length

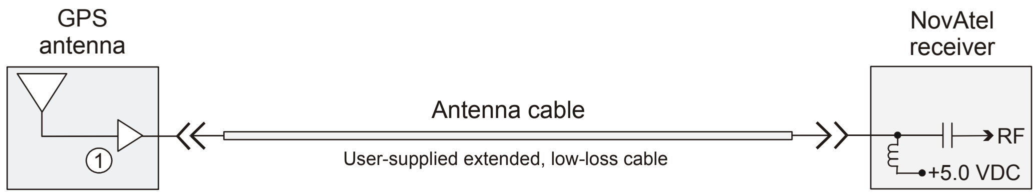
In some cases, the 30 meter RF cable available from NovAtel is not long enough. There are two basic methods that facilitate longer antenna cable runs:

1) Selecting specialized low-loss coaxial cables (passive method), or
2) Inserting additional cable lengths and adding in-line, low noise amplifiers between the GPS antenna, antenna cable, and receiver to keep the net gain at an acceptable level (active method).

3.6.1 Passive Cable Runs

The passive method of extending the remote location of the GPS antenna is achieved by selecting a high quality coaxial cable exhibiting low loss over extended lengths, as shown in *Figure 10*. Distances of 200 to 300 meters (656 to 984 feet) are possible by this method. The most important factor in selecting the cable is that its maximum loss over the desired length still provides for at least +15 dB, and preferably +20 dB of gain at the receiver's RF input. *Section 4* on page 13 provides information on suppliers of low-loss extended cables.

Figure 10 – Extended Length, Low-Loss Antenna Cable



① The antenna LNA is powered by +5.0 VDC from the receiver via the antenna cable center conductor.

One major disadvantage of specialized low-loss cables for long runs is that typically a larger diameter cable is required to reduce the signal losses. This in turn means that heavier, more rigid cable construction is required to manufacture the cable. Weight and flexibility may be a major factor in the practical limit for the cable length. A sharp rise in the cost per meter accompanies low-loss cables since special manufacturing methods and materials are required. Eventually, as distances become greater, a practical limit is reached where cost, weight, and rigidity become prohibitive factors.

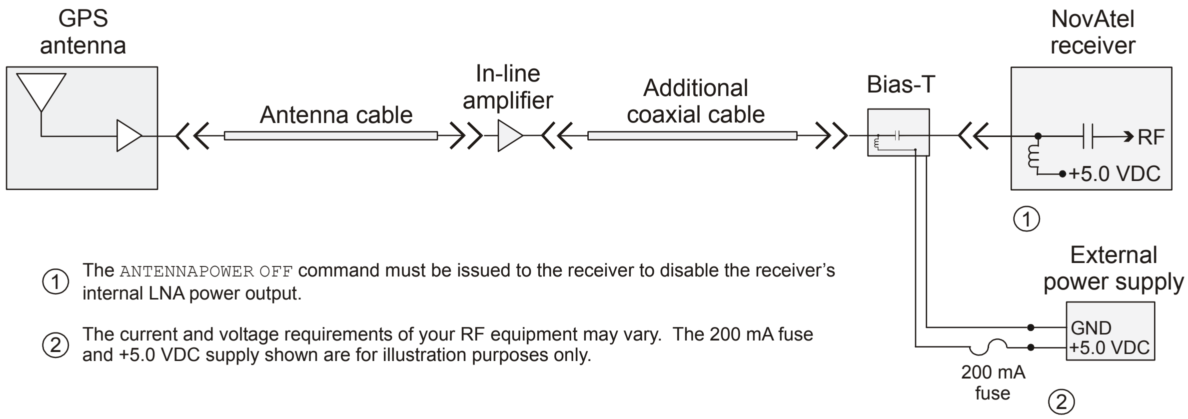
3.6.2 Active Cable Runs

In some cases, long cable runs may become more practical by using "active" methods. Increasing the distance between the GPS antenna and receiver by active means is accomplished by inserting one or more additional cable lengths and adding an in-line amplifier to negate the signal loss of each additional cable length.

The use of in-line amplifiers allows for smaller, less expensive, and more flexible coaxial cable as opposed to the larger, semi-rigid, low-loss cables. On the other hand, a good deal more hardware is required for the installation, such as one or more in-line amplifiers, an external power supply system for the amplifiers and possibly a DC block, coaxial connector adapters, and a bias-T to inject the external power supply through the coaxial cable.

A basic installation using an in-line amplifier powered by an external power supply through a bias-T is shown in *Figure 11*. The bias-T should include circuitry to prevent DC power from being fed back to the receiver. Because an external supply is being used, the receiver's internal LNA power output must be disabled using the `ANTENNAPOWER OFF` command. However, depending on the power requirements of the in-line amplifier and antenna, one of the other solutions for incorporating in-line amplifiers as discussed in *Section 3.1.3* starting on page 5 may be more suitable[2].

Figure 11 – Additional Cable Length with In-Line Amplifier



4 Suppliers[5]

This section provides information on suppliers and equipment that may meet your needs for the special cases mentioned in *Section 3*.

4.1 Low-Loss Cables

One source of low-loss coaxial cables is the Andrew Corporation. Andrew supplies low-loss HELIAX® cables of various sizes, loss values, and flexibility. To find out more about Andrew's products, visit www.andrew.com.

4.2 In-Line Amplifiers

Raven ATC and Mini-Circuits both offer suitable in-line, low-noise amplifiers. Raven ATC has developed an in-line amplifier that provides 20 dB of gain, with a low noise figure and low current consumption, which is ideal for use with an OEM4, OEMV, or SSII family receiver. For product details and contact information, visit http://www.ravenprecision.com/atc/GPS/Products/.

Mini-Circuits also offers inline amplifiers that can be used for an extended cable run or when the RF equipment loss is too great to meet the GPS receiver's input gain requirements. However, typically their in-line amplifiers require 15 VDC and, therefore, the configuration must follow that described in *Section 3.1.3.2* on page 5. An adapter may also be required, as Mini-Circuit's in-line amplifiers are typically supplied with BNC or SMA connectors. For further information, visit www.mini-circuits.com.

4.3 Other Equipment

In addition to providing in-line amplifiers, Raven ATC and mini-circuts also offer splitters and bias-Ts, as detailed at http://www.ravenprecision.com/atc/GPS/Products/ or www.minicircuts.com Any bias-Ts used should include circuitry to prevent DC power from

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[5] This section is provided for information purposes only. NovAtel does not endorse any of these suppliers or their products. The information provided was accurate at the time of publication. Confirm all specifications, models, and part numbers with the manufacturer prior to ordering.

being fed back to the receiver. GPS Networking, at www.gpsnetworking.com, specializes in custom parts and in-line TNC attenuators.

5 Additional Information

Various solutions for GPS antenna and cable setup have been offered in this application note. For more information and insight to alternative solutions, please contact NovAtel Customer Service.

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