

RF Considerations with the GS8 modular gateway

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1 Introduction

The GS8 modular gateway from Zed-3 accommodates modules for analog, GSM, and CDMA. The system permits connectivity of phone calls between any of these interfaces and the SIP interface on the ethernet port; it is unique in this functionality. The product allows a business or enterprise to make and receive calls on a cellular phone network from its PBX thereby providing cost savings, convenience, and improved customer service.



Selecting the proper module and having good RF connectivity to the cellular phone network will ensure a smooth and satisfactory deployment. This application note explains some of the things to consider when purchasing and installing the GS8 modular gateway.

2 GSM and CDMA Frequencies

2.1 GSM Frequency Bands

In principle the GSM system can be implemented in any frequency band. However there are four major frequency bands where GSM is used globally. GSM terminals may incorporate one or more of the GSM frequency bands listed below to facilitate roaming on a global basis. This table lists the common bands:

Generic Name	Up Link Frequency Band	Down Link Frequency Band
GSM850	824 ~ 849 MHz	869 ~ 894 MHz
GSM900	880 ~ 915 MHz	925 ~ 960 MHz
GSM1800	1710 ~ 1785 MHz	1805 ~ 1880 MHz
GSM1900	1850 ~ 1910 MHz	1930 ~ 1990 MHz

The up link (UL) is the signal from the terminal (usually a mobile handset) to the base station; the down link (DL) is the signal from the base station.

2.2 GSM900 and GSM1800

The GSM standard originated in Europe in June 1985. The initial frequency band determined to be used was GSM900. Later (mostly driven by the UK) GSM1800 was added. These two frequency bands were therefore adopted by most of the world:

- Europe
- Middle East
- Africa
- Asia¹

The following Latin America countries use these frequencies in addition to GSM850:

- Bolivia
- Brazil
- Guatemala
- El Salvador

The Caribbean has a mixture of frequencies.

2.3 GSM850 and GSM1900

When GSM technology moved to the US, it was impossible to use the same frequency bands that were in use in Europe and Asia because those had already been allocated to other devices by the FCC. A different pair of frequency bands was made available for GSM use: the 850 MHz and 1900 MHz bands. These frequencies are used in the US, Canada, and many other countries in the Americas.

In North America, initial implementations of GSM were exclusively 1900 MHz, with 850 MHz being added in 2001. In Canada, GSM1900 is the primary frequency used in urban areas with GSM850 as a backup, and GSM850 being the primary rural frequency. In the United States, regulatory requirements determine which area can use which frequency.

Cellular was the term used to describe the 850 MHz band, as the original analog cellular mobile communication system was allocated in this spectrum. Providers commonly operate in one or both frequency ranges. Today, the term is used generically to refer to any mobile communications.

PCS is an acronym for Personal Communications Service and represents the original name in North America for the 1900 MHz band.

1. Japan and South Korea do not use GSM900.

GSM1900 and GSM850 are also used in parts of South and Central America, and both Ecuador and Panama use GSM850 exclusively. As noted above, some countries in the Americas use GSM900 or GSM1800.¹

2.4 CDMA Frequencies

The CDMA networks use multiple frequencies in different regions. Zed-3 supports the 800 MHz band, namely:

- 824 ~ 849 MHz for the up link (UL)
- 869 ~ 889 (or 894) MHz for the down link (DL)

2.5 Implications for the GS8 modular gateway

Most GSM phones operate in a single frequency band or the two frequency bands in use in the region where the phone is sold (for example, China exclusively uses GSM900). A single band or dual band phone is simpler and cheaper to manufacture than a phone that supports all four bands. However, people who travel may need a phone to operate in three or all four bands. Such tri-band and quad-band capabilities are available in comprehensive models of phones.

Zed-3 offers three different GSM or CDMA modules:

- **90-05530**. Plug in module for GS8 modular gateway: one port GSM (900 MHz and 1800 MHz) for voice and SMS, without antenna
- **90-05535**. Plug in module for GS8 modular gateway: one port GSM (850 MHz, 900 MHz, 1800 MHz, and 1900 MHz) for voice and SMS, without antenna
- **90-05531**. Plug in module for GS8 modular gateway: one port CDMA (800 MHz) for voice and SMS, without antenna

The dual band GSM module serves most of the world. The quad band GSM module can be used everywhere; it is more expensive than the first module. The GSM module (and for comparison the FXO module) is shown below.

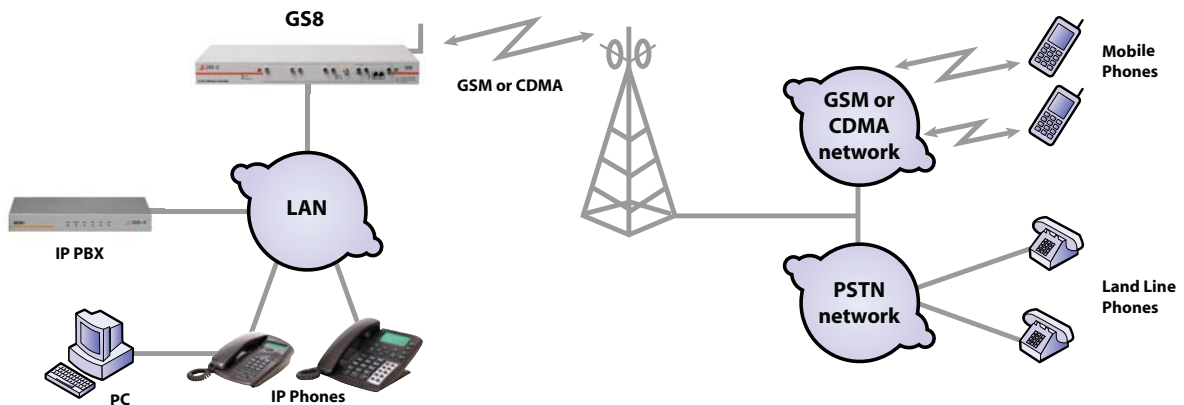


1. Some documents refer to GSM850 as an 800 MHz band because this frequency range was referred to as such when it was first allocated for AMPS usage in the US in 1983.

3 Positioning the GS8 modular gateway

3.1 Selection of a Site

In most applications, the GS8 modular gateway will be installed in a network room, adjacent to the IP PBX. This is a natural position as it can form part of the basic communications for the company and such a location can provide physical security:



However, the network room (or area) has many metal structures and much noise generated by adjacent network equipment. This will reduce the signal strength of the GSM or CDMA signal and impair its quality. Many commercial buildings use a high grade insulator in the roof that has aluminium foil on one side. This can significantly reduce the GSM or CDMA signal anywhere inside a building, leading to further losses inside the network room.

If the building has a metal roof or sides, that can act as a Faraday cage and significantly reduce or prevent any GSM or CDMA signal reaching the GS8 modular gateway.

As shown in the figure above, the GS8 modular gateway can be placed anywhere that can be conveniently reached by AC power and an ethernet cable.

Before deploying the GS8 modular gateway, walk around the area where you want to install the system with a mobile phone and watch the signal strength that it reports. If the signal strength is low, or if it changes as you move a few metres, the signal that could reach a GSM or CDMA module may be variable leading to poor quality communications. Most people find it difficult or impossible to use a mobile phone inside a commercial building and if that is the situation in the building where you want to deploy a GSM or CDMA gateway, you need to pay particular attention to the RF conditions.

3.2 Use of a Standard Antenna

The standard antenna mounts directly to the GSM or CDMA module and is shown in the figure to the right. The part number for this item is:

- **90-20500.** Antenna for plugging into GSM or CDMA module on GS8 modular gateway

The module and antenna have SMA connectors and the antenna screws into the module. You should not use any tools to tighten the antenna. You can use this antenna if:

- you have determined that there is a good GSM or CDMA signal where the GS8 modular gateway is installed
- you have installed only one or two GSM or CDMA modules in the GS8 modular gateway

As discussed above, a good position for the system may be near to a large window or high in the building, above the roof insulation (but not exposed to the weather).

When you have multiple GSM or CDMA modules in one GS8 modular gateway, the signals can potentially interfere with one another. The same is true if you place two mobile phones adjacent though in practice it is unusual for mobile phones to be used when they are less than one metre apart.

If you have two modules, install them in slots one and four. In a site where there is good signal this will generally work well.



4 Moving the Antenna from the Network Room

4.1 External Antenna

If you will locate the GS8 modular gateway where the RF signal is poor, you must place an antenna where the RF signal is good. Zed-3 sells a remote antenna and cable for this as shown in the figure below. The part numbers for these items are:

- **90-20502.** Coax cable, 10 m, with SMA male and female connectors
- **90-20503.** Remote antenna with magnet and 5 m coax cable

This remote antenna is a ground plane antenna. It has a magnet on its base and you should mount it on a metal surface. For more information about ground plane antenna see section 5.2 on page 8. The cable has 5 dB of loss. The end of the cable from the remote antenna can plug directly into the GSM or CDMA module. One end of the extension cable plugs into the module and the other end plugs into the end of the remote antenna.

Ensure that the antenna is vertically upright before using it. The signal quality will be degraded if the antenna is tilted or horizontal.

You should use the extension cable only if the signal strength where the antenna is placed is very good. If it is mediocre the signal loss in the 15 m of cable will cancel the effects of using the longer cable. In this case, you should source a better antenna and cable.

If you are installing multiple GSM or CDMA modules you can use multiple external antennae with each antenna wired separately to a module. Place each antenna at least 1 m apart. Preferably, you should make this separation vertical rather than horizontal. A better solution may be to use an antenna splitter as described in the next section.



4.2 Antenna Splitters

The antenna splitter takes a signal and splits it multiple ways. For the GS8 modular gateway there can be four paths, so Zed-3 offers a four way splitter.

- **90-20501.** Antenna splitter, 4 to 1, for GSM or CDMA, with 4 coax cables, each 0.5 m (requires antenna)

A splitter is also called a combiner because it takes the output signal from each of the modules and combines them to a single output antenna. You must be careful if you buy a splitter that is not rated as a combiner. The received signal is at a low level (mW) and the splitter does not have to handle much power. However, the output power from each module is 1 W and will destroy a splitter intended only for receive applications.

Most splitters, including that offered by Zed-3, are passive. Therefore if a signal is received and sent in equal measure to each port, each port receives one quarter of the signal, that is, -6 dB from the input signal. Similarly, the transmitted signal from one module is attenuated by 6 dB as it passes through the splitter on its way to the antenna. The 6 dB loss is for an ideal splitter; for the splitter supplied by Zed-3, the loss is 6.5 dB.



The splitter has one port to connect to the antenna and four other ports to connect to each of the modules. The splitter mounts on top of the GS8 modular gateway and short cables connect the splitter to each of the modules. If you use the splitter to connect to fewer than four modules, terminate the unused ports with 50 Ω dummy plugs.

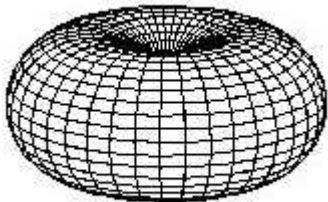
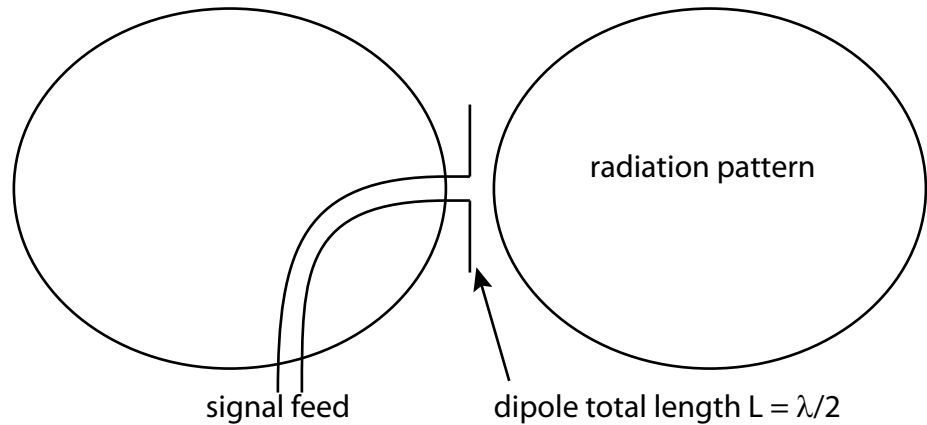
You would usually use an external antenna when you use a splitter. However, because of the losses in the cable and splitter, you may need a high gain antenna or a signal amplifier as described in the following sections.

5 Antenna Selection

5.1 The Dipole Antenna and its Gain

Most antenna are simple dipole antenna as shown in the figure to the right.

Such an antennae create a doughnut radiation pattern as shown below:



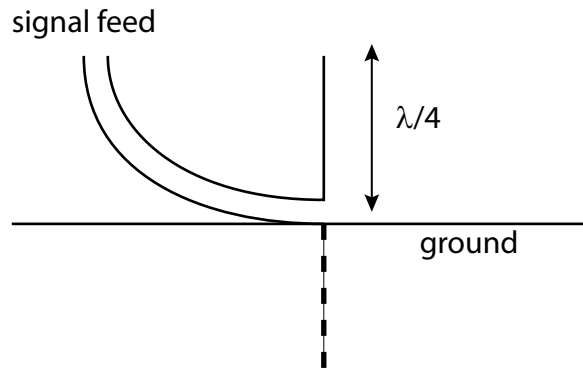
Lambda (λ) is the wavelength of the signal. For the highest and lowest frequencies shown in section 2.1 on page 1, $\lambda/2$ is 173 mm (at 824 MHz) and 72 mm (at 1990 MHz).

The radiation from the dipole is compared to that of an idealized antenna, the isotropic radiator. The isotropic radiator radiates uniformly but cannot exist for radio waves. The output from such an antenna is referred to as 0 dBi (gain relative to isotropic). The half wavelength dipole has a gain of 2.15 dBi.

5.2 The Ground Plane Antenna

This antenna (shown in section 4.1 on page 5) is also referred to as a quarter wave or unipole antenna, in which half of the dipole is deemed to be the ground. It is essential that the ground be a good conductor for this to function. The way this works is shown in the next figure.

The signal is radiated only upwards but has the same gain as the dipole antenna (2.15 dBi), assuming an infinite ground plane. The ground plane does not need to be electrically connected to ground. However, it must be sufficiently large to have a good effect. For GSM850, the size should be 700 mm and for GSM1900 it should be 300 mm in diameter.



The ground plane does not need to be solid; it can be a mesh, but you should place the ground plane antenna in the middle of the plane. You can use aluminium cooking foil to create a plane. Ensure that the antenna is upright and the ground plane is horizontal.

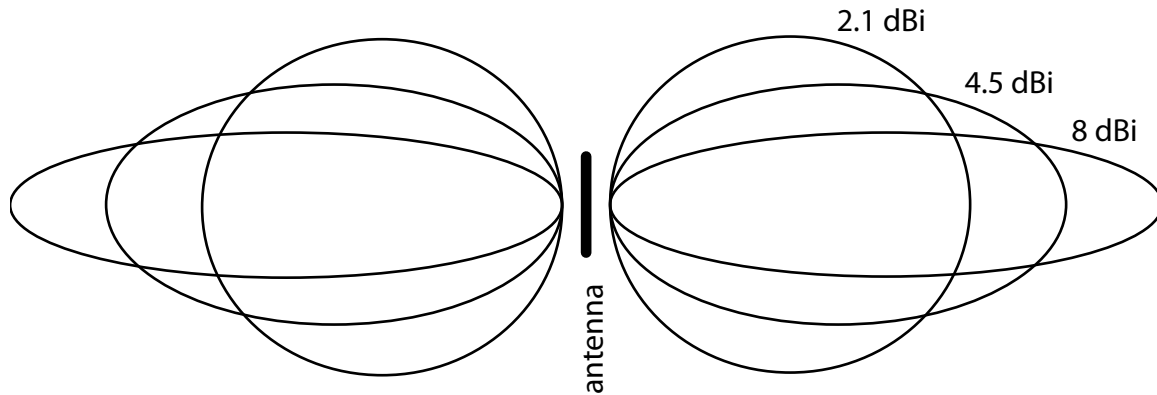
You can purchase antennae that have a ground plane built into them in the way of radial spurs as shown in the picture to the right.



5.3 Gains of different Antenna

When the length, L , of the antenna is changed, its gain also changes. For example, when the total length is equal to $1.5 \times \lambda$, the gain is 3 dBi, and at $8 \times \lambda$, the gain is 8.5 dBi. Sometimes, these gains are quoted using the standard dipole as the reference (that is, the dipole is 0 dBd). Then the antenna whose total length is $8 \times \lambda$ would be said to have a gain of 6.35 dBd.

However, as we modify the design of the antenna and increase the gain, the doughnut shaped radiation pattern is squashed flat. This gain is achieved at the expense of directionality as shown here:



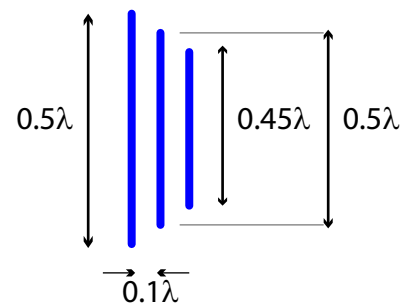
With the “higher gain” antenna it is possible to communicate with a cell site further away. However, the GSM or CDMA signals bounce off buildings in built up areas, and off mountains in a valley. Typically, a high gain antenna is best used in country areas where wide flat plains are between the GSM or CDMA module and the cell site or in a built up area where there is line of sight to the cell tower. In mountainous areas or in city environments, a high gain radiation pattern will not work as efficiently as a unity gain from a standard dipole. If a high gain antenna was used in a dip or valley and the GS8 modular gateway is at the lowest point, the phone signal would be weaker, as the signal would bounce off surrounding hills or buildings and find it difficult to reach a cell site. Or if the antenna is on a slope, the high gain antenna would be sending most of the signal into the sky. Therefore, a high gain antenna can result in a poorer signal when used in the wrong environment.

It is also important to remember that the GSM or CDMA module does not transmit more power nor does it make the input more receptive to weak signals just by installing a different antenna. By changing the antenna what we accomplish is to send the signal where it is required (or receive it from where it is being transmitted).

5.4 Yagi-Uda Antennae

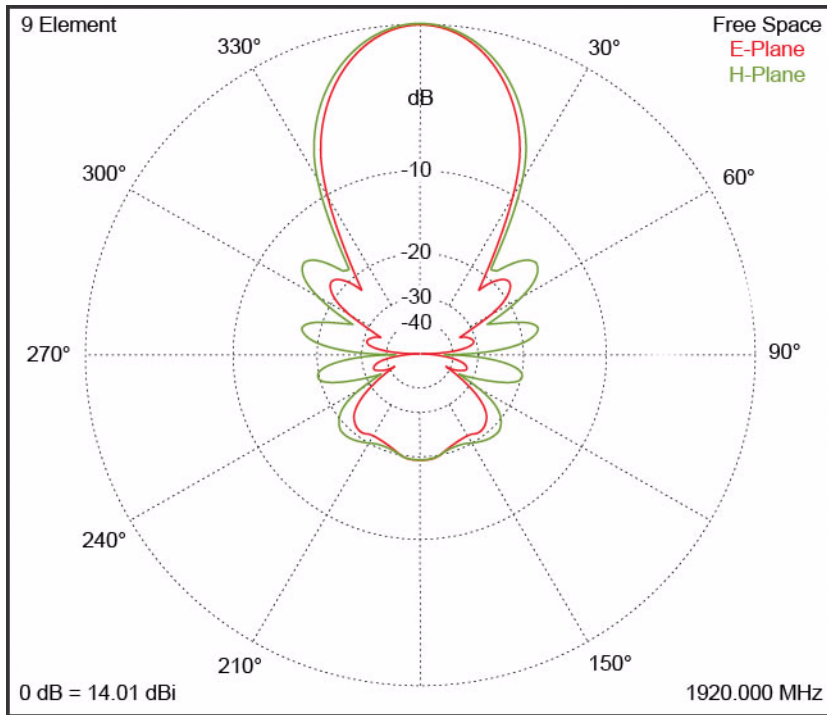
The dipole antennae are omni-directional, meaning they radiate (or collect) in a 360 degree pattern around the antenna. The Yagi-Uda antenna (commonly referred to simply as a Yagi antenna) is very unidirectional. This is achieved by having a collector (or driven) element that is equal to $\lambda/2$ (as in the standard dipole), a reflector element that is 10% longer behind the collector, and a director element that is 10% shorter in front of the collector.

The Yagi-Uda antenna has a gain determined by the number of director elements in front of the collector element. But just as with the dipole, the gain comes at the expense of directionality. Also,



since the size of each element must be precisely determined (to about one mm in length), a Yagi-Uda antenna usually serves the purpose of a single frequency band (for example, GSM1900 but not GSM850).

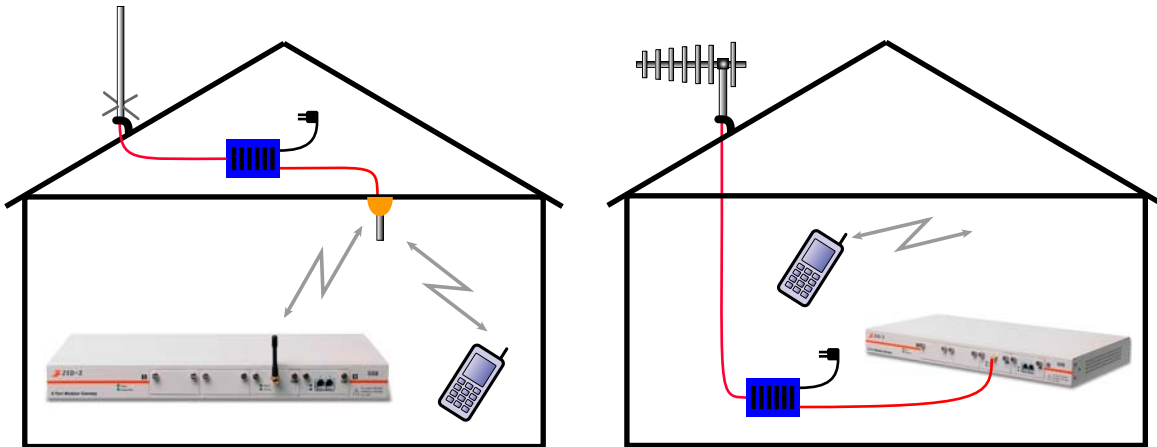
An example of such an antenna and its directionality pattern is shown below. This has a gain of 14 dBi and is intended for GSM1900 applications.



6 Signal Amplifiers

To boost the signal (either transmitted or received), you can use an active amplifier to increase the signal. As with a splitter, you must be careful to select one that is designed for bidirectional communications. You will destroy an antenna amplifier that is designed to amplify the received signal (such as a TV amplifier, for example).

These amplifiers are available in two different formats as shown here.



The amplifiers have three connections: external antenna, internal signal, and AC power. The amplifiers boost the signal from the external antenna and provide an increased signal to the terminal equipment. Simultaneously, they take the signal from the equipment inside the building and provide a stronger signal externally. These amplifiers have a gain between 10 dB and 60 dB. Some amplifiers are dual band but others are single band; you need to take care to select the proper amplifier to match the service in your area.

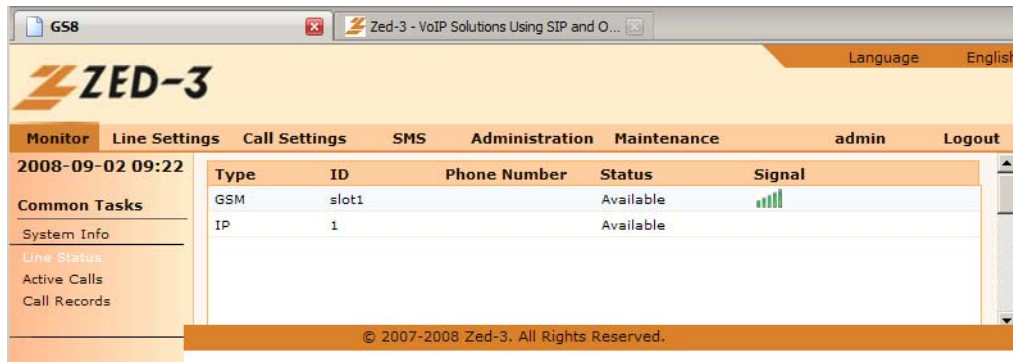
In the image on the left, the amplifier connects to an antenna inside the building. This makes the signal available for other terminals and is most useful if you need connectivity to mobile phones as well as the GS8 modular gateway. The disadvantage with this type of amplifier is that the internal and external antennae need to be physically separated. The separation usually should be 5 m vertically.

In the image on the right, the amplifier connects directly to the GS8 modular gateway (that is directly to the splitter or to the GSM or CDMA module). This limits where the signal can go but removes the restrictions about the placement of the external antenna. Other terminals (such as mobile phones) in the building do not benefit from the amplifier.

Although different antennae are shown in the figure, the proper selection of antenna will depend on factors outlined in the preceding sections.

7 Viewing the Signal Strength on the GS8 Modular Gateway

You can view the signal strength received by a GSM or CDMA module from within the Administration UI (after software version 1.0.6) of the GS8 modular gateway. This is shown in the figure below; the signal strength is indicated in much the same way as on a mobile phone, with a sequence of bars. The GSM or CDMA module must indicate at least one green bar to function.



8 Conclusion

The GS8 modular gateway can provide many benefits for your business and is simple to install and use. However, you must pay careful attention to the selection and placement of an antenna. If you use multiple GSM or CDMA modules, you should probably use a splitter so that you need only a single antenna. Finally, because many buildings have weak mobile phone signals where the equipment is placed, you may need an amplifier to boost the signal where you have installed the GS8 modular gateway.

9 About Zed-3

Zed-3 provides products that permit people to communicate simply, efficiently, and cost effectively. With careful attention to detail, these IP telephony products work seamlessly together and interoperate with products and services from other suppliers. Zed-3 can provide VoIP solutions to connect home workers, small businesses, and enterprises with multiple offices. Zed-3 has its headquarters in Milpitas, California and has offices in Bangalore, Beijing, and Singapore. The company's products are distributed in the Americas, Africa, Asia, Europe, and the Middle East.

For more information on Zed-3 or its products, access: <http://www.zed-3.com>.