Vaisala started deliveries of the RS90-AG radiosonde in November 2000 after extensive field testing. The new radiosonde belongs to the RS90 series, incorporating GPS-based windfinding. It completes the RS90 series along with the earlier models, the RS90-A and the RS90-AL. Finally, both Loran-C and GPS-based windfinding options are available together with the high, uniform quality PTU (pressure, temperature and humidity) measurements that are provided by the RS90 transducer.

The RS90-AG radiosonde was designed to be fully compatible with existing ground equipment, so no upgrades are needed for ground stations that are already compatible with RS80 GPS soundings and RS90 PTU (pressure, temperature and humidity) soundings.

**RS90 radiosonde models**

The design was based on existing RS90 radiosonde electronics integrated with Vaisala’s GPS receiver technology. GPS receivers have been used with RS80 radiosondes since 1997.

The transducer used in the RS90-AG is the same as that used in the RS90-A and RS90-AL. The similar type of transmitter is also used in the other RS90 models.

The GPS receiver in the RS90-AG is basically the same as the one used in the GPS121 module (this module is used in the RS80 series GPS sondes and in dropsondes). The GPS electronics have been modified, but the operating principle is corresponding to the one used in the GPS121 module.

**Accurate RS90 transducer**

Vaisala News No. 136/1995 provided an introduction to the structure of RS90 sensors, so this article will only give an overview of the RS90 transducer.

Table 1. RS90 radiosonde models available.

<table>
<thead>
<tr>
<th>Model</th>
<th>Transmitter</th>
<th>Sensors</th>
<th>Wind finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS90-A</td>
<td>400 MHz</td>
<td>PTU</td>
<td>-</td>
</tr>
<tr>
<td>RS90-AL</td>
<td>400 MHz</td>
<td>PTU</td>
<td>Loran-C</td>
</tr>
<tr>
<td>RS90-AG</td>
<td>400 MHz</td>
<td>PTU</td>
<td>GPS</td>
</tr>
</tbody>
</table>

In several tests, RS90 sensors have demonstrated their supremacy over RS80 sensors. One of the tests, performed in May 1997 in Vienna, was summarized in Vaisala News No. 147/1998. The following are the main advantages that the RS90 sensors have over RS80 sensors:

**Thin-wire temperature sensor (F-THERMOCAP®):**

- Better overall accuracy
- Short response time due to low thermal mass
- Low radiation error

**Silicon micro-machined pressure sensor (BAROCAP®):**

- Better overall accuracy
- No measurement errors when ambient temperature changes rapidly
- Insensitive to transportation shocks
Reduced icing in freezing conditions
Short response time
Better overall accuracy

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Figure 2. Block diagram of Vaisala’s codeless GPS receiver.

Figure 1. RS90 radiosonde transducer: (1) Pressure sensor, (2) Temperature sensor, (3) Humidity sensors, (4) Protective cap, (5) Sensor boom, (6) Transducer electronics, (7) 10-pin interface connector.

Structure of RS90-AG sonde

The RS90-AG is fitted into the ‘common’ RS90 mechanics with minor modifications. The major visual difference is the GPS antenna next to the sensor boom. This antenna (Quadifilar Helix) is of the same type that is used in the GPS121 module. The antenna PCB is covered with a plastic strip, which is necessary because excess humidity or rain on the antenna PCB (printed circuit board) can change the impedance of the antenna and thus attenuate the signals tracked.

Improved windfinding performance

The performance of the GPS sounding system has been improved over the last three years and the RS90-AG is fully utilizing these improvements.

Below is a short description of major improvements relating to the GPS sounding system:
- WAAS satellite signal rejection: WAAS satellite signal identification and rejection in ground equipment software eliminate WAAS signal interference in windfinding. (WAAS = Wide Area Augmentation System)
- Two phase unwinder: the reliability of the unwinder was improved through new design. This significantly reduced the number of unwinder sticks during launch.
- Improved GPS receiver electronics: GPS module electronics were modified for better signal-to-noise ratio and for higher short and long term frequency stability of the receiver.
- Wider GPS intermediate frequency (IF) bandwidth: ground equipment software was modified to tolerate wider IF drift of the radiosonde.
- GPS module pre-aging and production humidity control: pre-aging of the oscillator circuitry and production humidity control improve the short and long term frequency stability of the receiver.

RS90-AG field and pilot tests

Three main test series were performed to verify the wind finding capabilities of the sonde.

The three stations represented different environments: one was located in Jokioinen, Finland, another in Vienna, Austria, and the third in Kuala Lumpur, Malaysia. Conditions in Malaysia were expected to be more difficult than in the other places, for two reasons:
- Ionospheric scintillation is strongest in equatorial areas. Strong scintillation affects GPS satellite signal propagation and may degrade the performance of the GPS receiver.
- Extremely cold temperatures during sounding, due to the tropical atmosphere. Temperatures as low as -90 °C occur in the tropopause levels (height of 10-15km), which the sonde electronics and battery have to be able to cope with.

All in all, 96 soundings were carried out with 600 g balloons and standard uplift. The results showed that there was no great difference in performance between the three test locations.
The major interest, however, was on a performance comparison between the RS80 GPS sondes and the RS90-AG. For this comparison, data from RS80 GPS soundings was collected in sounding conditions similar to those in the RS90-AG pilot tests. Performance analysis, with emphasis on data availability, was carried out. Although comparable data was available for only part of the soundings, the results were convergent. The overall conclusion was that raw wind data availability in RS90-AG soundings was at the same level or higher than in RS80-15G soundings. The advantage of the RS90-AG design is the firm and solid construction of the sonde, with good internal isolation between the GPS receiver and the 400 MHz transmitter.

Figure 3. Structure of the RS90-AG radiosonde.

1. GC Interface
2. Suspension rib (cover for GC Interface)
3. Battery activation in AUTOSONDE
4. Battery compartment lid
5. Temperature sensor
6. Humidity sensors (2)
7. Sensor boom
8. Transducer, with pressure sensor inside
9. Battery connector
10. Transmitter/Wind receiver board
11. 400 MHz telemetry antenna
12. Ground plane
13. Battery
14. GPS antenna

Global Positioning System

Trying to figure out where you are and where you are going is probably one of man’s oldest needs. Navigation and positioning are crucial to so many activities, and yet the process has always been quite problematic. Over the years various technologies have been used to simplify the task. Finally, the U.S. Department of Defense decided that the military had to have an extremely precise form of worldwide positioning.

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these ‘man-made stars’ as reference points to calculate positions. In a sense, it is like giving every square meter on the planet a unique address. GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. That makes the technology accessible to virtually everyone. These days GPS is finding its way into cars, boats, planes, construction equipment, movie-making gear, even laptop computers. Vaisala uses GPS in its wind finding system.

GPS was designed for high accuracy and worldwide coverage. The satellites orbit the earth at a distance of approximately 20,000 km in six orbital planes, each at an inclination of 55 degrees.

Each satellite continuously transmits a digitally-modulated spread spectrum signal on two carrier frequencies (1.226 GHz and 1.575 GHz) with a power level below thermal background noise. Both carriers are modulated with the military P/Y code, so the effective signal is 20 MHz wide. The 1.575 GHz carrier is also modulated with a ‘civil’ version, called the C/A code, which makes the effective signal 2 MHz wide.

Vaisala produces an upper air sounding system in which the wind finding is based on GPS. This concept offers good vertical resolution and accuracy of radiosonde wind profiling. Accurate three-dimensional positioning, and wind computation require four satellites. Using more than four satellites simultaneously is an advantage, because an ideal geometrical configuration can then be formed.