
# BHW Technologies (博泓微科技有限公司)

## Advanced RF IC, Antenna, Filter, RF Front-End and Wireless System Solutions

## BHW Application Note #012

# Enabling Cost-Effective High-Precision GNSS Using BHWL161 and Linear-Polarization PCB Antenna

Rev. 1.4

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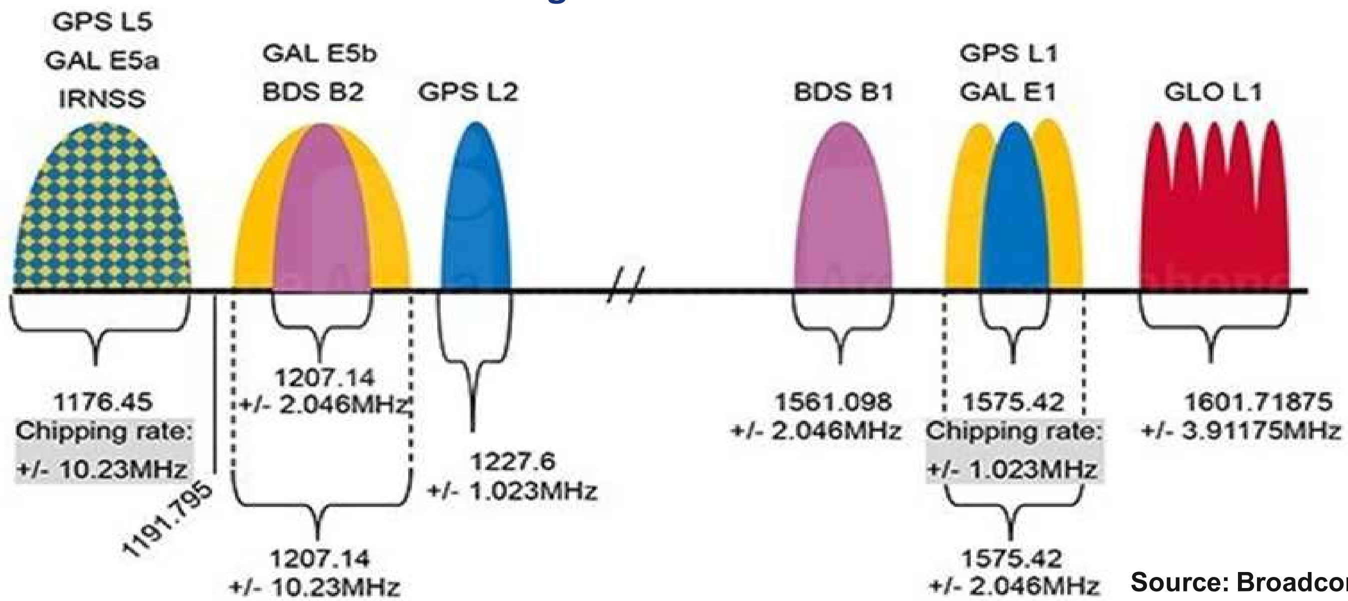
# Background: Next-Gen High-Precision GNSS

**Technical Challenges for Dual/Multi-Band GNSS:**

- **Multi/Wide-Band Antenna**
- **LNA with Low NF and Sufficient Gain over Wideband**
- **High Input P1dB/IIP3 for Anti-Jamming and Desensitization**
- **New System Architecture, Implementation and Optimization**
- **Low Cost for Best-Class Performance**
- **Typical Ceramic-Based Circularly-Polarized Antennas have Narrow Bandwidth and Limited Radiation Efficiency**
- **Multiple Ceramic Antennas Need to be Stacked to Achieve Dual/Multi-Band GNSS Operation**
- **Sufficient Ground Plane Extension underneath the Ceramic Antenna is Needed Typically for Optimal Performance**

**This AppNote provides theoretical analysis and test results of GNSS C/N0 using circular vs linear polarization antennas, as well as proposal for a high-performance, cost-effective dual/multi-band GNSS architecture using linear-polarization antenna and BHWL161 LNA with potential for monolithic integration of the entire GNSS receiver front-end into a single PCB.**




Source: Broadcom

# GPS L1 C/A-Code Link Budget

| Parameter | Satellite at Low Elevation (EL=5 Degree) | Satellite at Moderate Elevation (EL=40 Degree) | Satellite at Zenith (EL=90 Degree) |
|---|---|---|---|
| Satellite Transmit Power Pt in W | 27 | 27 | 27 |
| Satellite Transmit Power Pt in dBW | 14.3 | 14.3 | 14.3 |
| Satellite Antenna Gain (dB) | 12.1 | 12.9 | 10.2 |
| EIRP toward the Earth (dBW) | 26.4 | 27.2 | 24.5 |
| Range (km) | 25,240 | 22,020 | 20,190 |
| Path Loss (1/(4*pi*R^2)) (dB/m^2) | -159.0 | -157.8 | -157.1 |
| Atmospheric Loss (dB) | 0.5 | 0.5 | 0.5 |
| Received Power Density (dBW/m^2) | -133.1 | -131.1 | -133.1 |
| Effective Area of Omni Rx Antenna (dB*m^2) | -25.4 | -25.4 | -25.4 |
| Receive Power Available from Omni Antenna | -158.5 | -156.5 | -158.5 |
| Gain of Typical Rx Antenna (dBi) | -4 | 2 | 4 |
| C/A-Code Received from Typical Antenna (dBW) | -162.5 | -154.5 | -154.5 |
| C/A-Code Received from Typical Antenna (dBm) | -132.5 | -124.5 | -124.5 |

Source: Pratap Misra and Per Enge, Global Positioning System, Revised 2nd Edition, 2011.

**Notes and Comments:**

- The above analysis applies to GPS L1 C/A-Code only
- Typical GPS satellite broadcasts 2~4dB more power than the rated Tx power of 27W
- Other GNSS satellites such as BDS has different range (height) and higher transmit power
- The Rx antenna is assumed to have perfect right-handed circular polarization (RHCP)
- Due to limited radiation efficiency of popular GPS Rx antennas such ceramic patches, actual antenna gain might be lower, resulting in slightly lower received signal levels
- Considering the extremely low received signal levels, it is crucial to use a combination of best-class LNA (with lowest NF and highest linearity) and high-efficiency antenna in order to achieve optimal GNSS system performance (C/N0), as shown in the next page

# C/N0 of RHCP vs Linear Polarization Antenna

## RHCP Antenna with Moderate Efficiency LNA with Mediocre NF

**C/N0 Calculator for GPS L1 C/A-Code**



| Category | Parameter | Value | Unit |
|---|---|---|---|
| Fixed Parameters | Satellite Transmit Power Pt in Watt | 27 | W |
| | Satellite Transmit Power Pt in dB | 44.3 | dBm |
| | Satellite Altitude Height | 20200 | km |
| | Carrier Wavelength | 0.1904 | m |
| | k (Boltzmann's Constant) | 1.3806E-23 | J/K |
| Almost-Fixed Parameters | Atomspheric Loss | 0.5 | dB |
| | Ambient Temp Tamb in Celsium | 25 | Deg C |
| | Ambient Temp Tamb in Kelvin | 298.15 | K |
| | Satellite Antenna Gain Gt | 10.5 | dBi |
| | Antenna Temperature TA | 130 | K |
| Variable Design Parameters | System Noise Figure | 1 | dB |
| | Rx Antenna Directivity | 5 | dBi |
| | Rx Antenna Efficiency | 60% | % |
| | Rx Antenna Pol. Loss (0/3 for Cir./Linear) | 0 | dB |
| Calculated Results | Received Carrier Power C | -125.4 | dBm |
| | Effective Temperature Teff | 207.2 | K |
| | Effective Noise Density N0 in Watt | 2.8606E-21 | Watt |
| | Noise Power Density N0 | -175.4 | dBm/Hz |
| | Maximum C/N0 | 50.0 | dB-Hz |

## Linear Pol. Antenna with High Efficiency LNA with Best-Class NF

**C/N0 Calculator for GPS L1 C/A-Code**

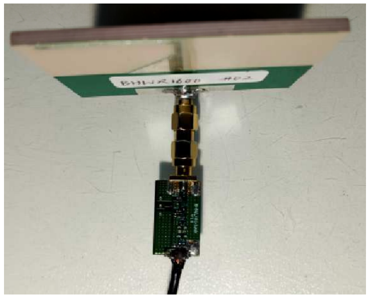


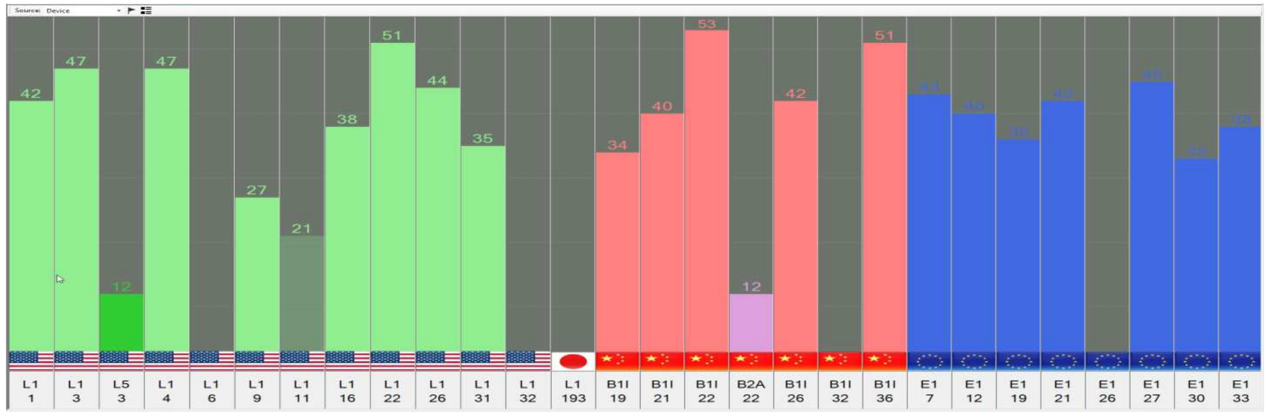
| Category | Parameter | Value | Unit |
|---|---|---|---|
| Fixed Parameters | Satellite Transmit Power Pt in Watt | 27 | W |
| | Satellite Transmit Power Pt in dB | 44.3 | dBm |
| | Satellite Altitude Height | 20200 | km |
| | Carrier Wavelength | 0.1904 | m |
| | k (Boltzmann's Constant) | 1.3806E-23 | J/K |
| Almost-Fixed Parameters | Atomspheric Loss | 0.5 | dB |
| | Ambient Temp Tamb in Celsium | 25 | Deg C |
| | Ambient Temp Tamb in Kelvin | 298.15 | K |
| | Satellite Antenna Gain Gt | 10.5 | dBi |
| | Antenna Temperature TA | 130 | K |
| Variable Design Parameters | System Noise Figure | 0.5 | dB |
| | Rx Antenna Directivity | 5 | dBi |
| | Rx Antenna Efficiency | 90% | % |
| | Rx Antenna Pol. Loss (0/3 for Cir./Linear) | 3 | dB |
| Calculated Results | Received Carrier Power C | -126.6 | dBm |
| | Effective Temperature Teff | 166.4 | K |
| | Effective Noise Density N0 in Watt | 2.297E-21 | Watt |
| | Noise Power Density N0 | -176.4 | dBm/Hz |
| | Maximum C/N0 | 49.7 | dB-Hz |

- **There are only three major parameters that allow design optimization in a typical GNSS receiver: System Noise Figure, Antenna Gain, and Antenna Polarization (3dB loss if linear-polarization antenna is used).**
- **NF is of paramount importance: Every 0.1dB counts!**
- **As shown above, a linear-polarization antenna with high efficiency, in combination with LNA with lowest-available NF and best-class linearity, could result in GNSS receivers with comparable or better C/N0 than RHCP ceramic antenna.**
- **C/N0 of 50~53dB was obtained routinely with BHWL160/L161, due partially to 2~4dB higher transmit power from GNSS satellites.**
- **BHWL160/L161 GaAs broadband LNAs provide the industry's lowest NF and linearity over full GNSS bands, to help achieve best-class GNSS system performance, using either RHCP or linear-polarization antennas**

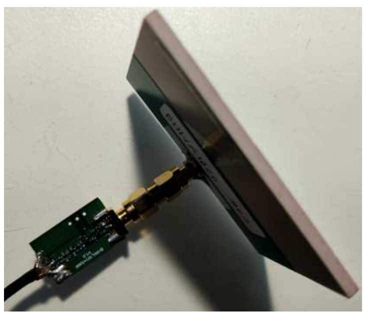
# Case Study 2: Dual-Band GNSS Architecture

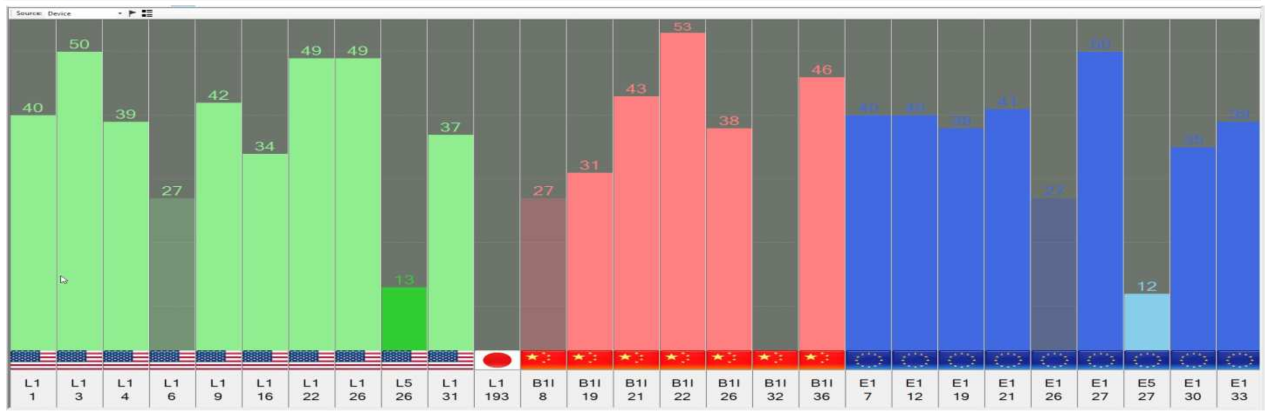
**Base (Arbitrary Orientation)**
**Max. C/N0=53dB**



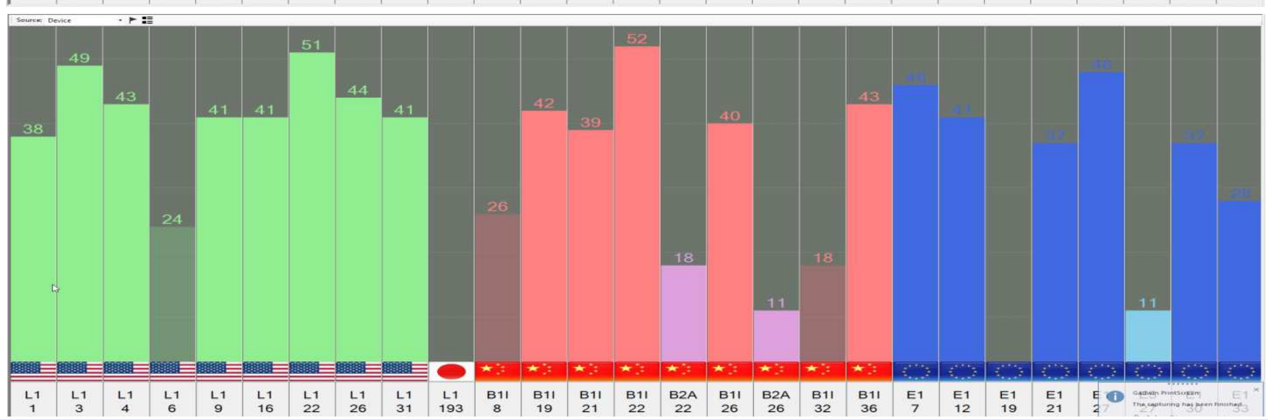



**Antenna Rotated by 45 Degree**
**Max. C/N0=53dB**






**Antenna Rotated by 90 Degree**
**Max. C/N0=52dB**



***This is an abridged version of BHW AppNote #012. Please contact BHW Support or your local sales rep/distributor for a complete copy of the document and other related information.***

# BHW RF Front-End Solutions AppNote Library

**In addition to standard datasheets and EVB/BOM info, BHW publishes an AppNote series that address various topics on RF front-end design and performance over a wide frequency range from 300MHz to 6GHz, as an effort to assist customers in developing cutting-edge, cost-competitive products:**

- BHW AppNote #001 - Cross-Over Cascade of BHWM253 to Boost Tx Power and Rx Sensitivity of 2.4GHz Systems
- BHW AppNote #002 - Accurate Benchmark of GNSS CN0 Using the Power-Splitter Method
- BHW AppNote #003 - Boosting Wi-Fi Tx Power and Rx Sensitivity with BHWA251 and BHWM252
- BHW AppNote #004 - UHF 900MHz RF Front-End Solution Using BHWA251 Half-Watt PA and BHWL160 Sub-1dB-NF LNA
- BHW AppNote #005 - Sub-1GHz Applications of BHWA350 2-in-1 Wideband Fully Matched Amplifier
- BHW AppNote #006 - Low-Noise High-IIP3 LNB Architecture for Dual-Band High-Precision GNSS Using Cascade of BHWL160
- BHW AppNote #007 - UWB RF Front-End Solution Using BHWA350 and BHWM552
- BHW AppNote #008 - High-Power 5.8GHz RF Front-End Solution Using BHWA555 and BHWM552 for ETC, V2X and Wireless Video
- BHW AppNote #009 - 5.8GHz RF Front-End Using BHWA350 and BHWM552 for Wireless Audio
- BHW AppNote #010 - Multi-Constellation GNSS Active Antenna Using BHWL161 Cascade and Single-Fed Dual-Band Antenna
- BHW AppNote #011 - BHWL161 Super-Compact Low-Power Low Noise Amplifier for Range Extension of 2.4GHz RC and IoT
- BHW AppNote #012 - Enabling Cost-Effective High-Precision GNSS Using BHWL161 and Linear-Polarization PCB Antenna
- BHW AppNote #013 - GNSS Noise Floor vs Receiver Architecture
- BHW AppNote #014 - Designing Ultra Low-Power High-Performance GNSS Products Using BHWL160 GaAs PHEMT LNA
- BHW AppNote #015 - BHWL161 GNSS Full-Band High-Performance LNA in Super-Compact 1x1mm DFN with Relaxed Pin Pitch
- BHW AppNote #016 - Improving GNSS NF Measurement Accuracy Using Broadband LNA BHWL161 as Pre-Amp
- BHW AppNote #017 - High-Efficiency, Low-NF 2.4GHz Front-End Solution for IoT Using BHWA251 and BHWM252
- BHW AppNote #018 - Optimizing BHWA555 Wideband One-Watt PA for Long-Range 5.8GHz Transmitter Applications
- BHW AppNote #019 - Miniature 2.4GHz RF Front-End with Integrated Chip Antenna and BHWM253 for TWS and IoT
- BHW AppNote #020 - Multiplying the Range for 2.4GHz Music Streaming with BHWR250L Active Integrated Antenna (AiA)
- BHW AppNote #021 - Range Extension for 2.4GHz Wireless Systems with BHWR250M Active Integrated Antenna (AiA)
- BHW AppNote #022 - Enabling Long-Range Angle-of-Arrival for High-Precision Indoor Positioning with BHWR250N RF AiA
- BHW AppNote #023 - Extend the Range for 5.8GHz Audio/Video Streaming with BHWR580M Active Integrated Antenna (AiA)
- BHW AppNote #024 - Improving 5.8GHz Radio Link Budget with BHWR580L Active Integrated Antenna (AiA)
- BHW AppNote #025 - Improving Range and Throughput of 2.4GHz Wi-Fi with BHWR250 Array Antenna
- BHW AppNote #026 - Improving Range and Throughput of 5GHz Wi-Fi with BHWR550 Array Antenna
- BHW AppNote #027 - Multi-Band High-Accuracy GNSS Solutions Using BHWP150 DFN1x1 Ultra-Compact Power Divider & Combiner
- BHW AppNote #028 - Use BHWM252 Cascade to Extend Range of 2.4GHz Wireless Systems with Single-Port SoCs
- BHW AppNote #029 - Improving Range of 2.4GHz Wireless Microphones and Audio Systems with BHWR250A Active Integrated Antenna (AiA)
- BHW AppNote #030 - Simultaneous Improvement in Range and Battery Life of 2.4GHz Wireless Systems with BHWR250M AiA

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