BLOOMICE TECHNICAL WHITE PAPER

Choosing the Right Antenna for Cellular, Wi-Fi, GNSS and LPWAN

A practical framework for matching antenna technology to the complete connected product

Antenna selection is not a search for the highest gain or smallest package. It is a system decision shaped by frequency, bandwidth, product geometry, ground plane, enclosure, installation and orientation. The right choice delivers repeatable link margin in the finished device.

There is no universally 'best' antenna. An embedded antenna may suit a plastic sensor but fail inside a metal cabinet. An external antenna can be more predictable, yet adds connector, cable, sealing and installation requirements. Selection must begin with the use case.

Four radio families, four different priorities

Frequency ranges below are indicative. Exact bands, regulatory limits and operator requirements depend on the radio, product variant and market.

RADIO	TYPICAL SPECTRUM	PRIMARY CHALLENGE	SELECTION PRIORITY
CELLULAR	Sub-6 GHz mobile bands, from below 1 GHz to several GHz.	Wide bandwidth, regional variants, body loss, feed loss and MIMO integration.	Balanced efficiency across every band; verify TRP/TIS and network behaviour.
WI-FI	2.4 GHz, 5 GHz and, where supported, 6 GHz.	Multi-band response, MIMO correlation, enclosure loss and Bluetooth coexistence.	Reliable patterns and isolation; verify throughput and receiver sensitivity.
GNSS	L-band: usually L1/E1/B1 near 1.575 GHz; optional L2/L5-class bands.	Weak signals, sky view, polarisation, device noise, filtering and ground plane.	Low system noise and upper-hemisphere coverage; verify acquisition and tracking.
LPWAN	Often regional 433, 868 or 915 MHz ISM bands; NB-IoT/LTE-M are cellular.	Long wavelength, limited space, ground dependence and mounting surfaces.	High efficiency at the operating channel; verify packet success in representative sites.

Decisions to make before looking at part numbers

1. **Define the radio requirement.** List technologies, bands, markets, operators, data rates, receive sensitivity, transmit power and simultaneous-radio modes.
2. **Define the physical environment.** Record PCB size, available ground, enclosure and mounting materials, antenna volume, cable route and nearby metal or batteries.
3. **Define the operating environment.** Include device orientation, user proximity, weather, vibration, obstructions, mobility, installation variability and expected coverage.
4. **Define measurable acceptance criteria.** Set limits for match, efficiency, realised gain, pattern, isolation, correlation, receiver desense and field-level performance.

MATCH THE ANTENNA FORMAT TO THE PRODUCT

Antenna formats: strengths, trade-offs and best use

Component type is only a starting point. Most embedded antennas depend on the host PCB, ground plane, clearance and enclosure; external antennas depend on the feed, connector and installation. Datasheet performance should never be treated as finished-device performance.

FORMAT	STRENGTHS	WATCH-OUTS	TYPICAL FIT
PCB trace	Low component cost; repeatable on a stable PCB; tuned to the product.	Uses edge area and keep-out; dependent on board and enclosure.	High-volume products with controlled PCB geometry.
Chip or ceramic	Compact catalogue option; straightforward assembly.	Needs specified ground and clearance; size can limit bandwidth and efficiency.	Space-limited embedded designs with suitable ground.
FPC or flexible	Thin, conformable and easy to reposition.	Adhesive, bend, cable route and mounting surface create variation.	Plastic enclosures and irregular internal surfaces.
Stamped metal / spring	Potentially efficient and repeatable; uses three-dimensional volume.	Mechanical tolerance, tooling and contacts need control.	Products with stable high-volume mechanics.
External whip / paddle	Separates the antenna from electronics and metal; often broad-band.	Connector/cable loss, exposure, sealing, cost and orientation.	Gateways, metal cabinets and demanding coverage.
Patch	Directional and circular-polarised options suit GNSS.	Needs ground, orientation and sky view; nearby materials can detune it.	Fixed-orientation GNSS receivers and gateways.

Technology-specific selection guidance

5. **Cellular.** Prioritise efficiency across the full required band set, not a single peak. Allow for regional variants, primary and diversity/MIMO elements, realistic cable loss and the effect of the enclosure, battery and user's body.
6. **Wi-Fi.** Choose dual- or tri-band coverage only where required, then engineer MIMO spacing, orientation, isolation and low correlation. Test 2.4 GHz coexistence with Bluetooth and account for greater feed loss at 5/6 GHz.
7. **GNSS.** Provide an unobstructed upper-hemisphere view wherever possible. Select passive or active architecture from feed loss and receiver noise requirements; an active antenna also needs LNA power, filtering and protection from overload or self-generated noise.
8. **LPWAN.** At sub-GHz frequencies, protect ground-plane and antenna volume early. An external antenna is often the most predictable choice for metal housings; embedded options must be tuned and validated on the real mounting surface.

Do not select by peak gain alone. Review efficiency, realised gain and full radiation patterns across every band. For MIMO, add isolation and correlation; for GNSS, include noise figure, filtering and sky-facing coverage. A headline value cannot describe system behaviour.

A practical antenna-selection workflow

Selection should progressively replace assumptions with measurements. Each stage narrows the options while protecting the mechanical and RF conditions needed for repeatable performance.

STAGE	ACTION	OUTPUT
1. Requirements	Map radio variants, bands, markets, MIMO/GNSS needs, range, battery target and deployment constraints.	Technology and acceptance matrix.
2. Architecture	Choose embedded or external; reserve antenna volume, ground, keep-out, feed route, connector and mounting clearance.	Integration concept and design rules.
3. Candidate screening	Compare reference designs, dimensions, bandwidth, efficiency, patterns, power rating, environmental rating and supply continuity.	Shortlist with explicit trade-offs.
4. Integrated prototype	Install candidates on representative PCB and mechanics; tune matching and control cable, adhesive and assembly details.	Conducted measurement and tuned build.
5. OTA and field validation	Measure efficiency, gain, patterns, isolation and desense, then verify network, packet or positioning KPIs in difficult sites.	Evidence against acceptance limits.
6. Production control	Freeze RF-critical geometry and materials; define incoming, assembly and installer checks; monitor fleet performance.	Released specification and control plan.

Useful starting points - not substitutes for validation

APPLICATION	LIKELY STARTING POINT	VERIFY ESPECIALLY
Plastic asset tracker	Embedded wideband cellular or LPWAN element; dedicated sky-facing GNSS antenna where positioning matters.	Battery, body proximity, orientation and limited ground.
Metal utility cabinet	External bulkhead or remote antenna; separate GNSS with clear sky view if required.	Cabinet shielding, cable loss, sealing and installer routing.
Wi-Fi gateway	Two or more external or well-separated embedded elements designed as a MIMO system.	Isolation, correlation, Ethernet/power noise and wall mounting.
Compact portable device	Custom-tuned FPC, chip or PCB solution, with architecture chosen around the user's hand and battery.	Detuning, absorption, changing orientation and coexistence.

Selection release checklist

9 Does the antenna cover every required band, market and radio operating mode?
10 Is its required ground, keep-out, orientation, feed and mounting condition preserved?
11 Has it been measured in the final or genuinely representative device assembly?
12 Have efficiency, realised gain, patterns, cable loss, isolation and receiver desense been assessed?
13 Have weak coverage, difficult orientations, users, walls, metal and simultaneous radios been tested?
14 Are RF-critical production, supplier and installation variables documented and controlled?

The right antenna is the one proven in the right product and environment. Bloomice supports requirements definition, antenna selection, RF integration, tuning, conducted and over-the-air testing, field validation and production readiness for connected products.

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