INFINITION

BR-12201 Doppler Radar System

Ultra-High-Frequency In-Bore Velocity Measurement for Small-Calibre Weapons

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1. Introduction

This document presents the Infinition BR-12201 Doppler Radar System: an ultra-high-frequency 122.5 GHz radar dedicated to in-bore measurement – the measurement of the projectile while it is still accelerating inside the gun barrel – together with the JB-6e junction box and TestCenter 7, the latest generation of Infinition's radar signal processing software.

The BR-12201 has a vocation of its own. Interior ballistics is where propellant burn, friction and projectile behaviour actually determine what leaves the muzzle, and on small calibres that phase has until now been largely inaccessible to direct measurement. Operating in continuous wave at 122.500 GHz, the BR-12201 works at a wavelength of about 2.4 mm – short enough for the energy to propagate inside a small-calibre barrel and to resolve the projectile as it accelerates. In-bore measurement is possible from 5.56 mm upwards, and down to 4.7 mm with additional mode correction.

> **The BR-12201 and all Infinition radars are renowned for their reliability over long periods of time, maximizing our customers' operational availability and the efficiency of their measurement campaigns. Our fast, personalized customer service keeps users up and running as much as possible.**

2. System Overview

A complete BR-12201 measurement chain consists of five main elements: the BR-12201 radar antenna with its permanently attached signal module, the reflector that folds the radar beam onto the bore axis, the muzzle trigger (AT-01 acoustic or OT-01 optical) installed near the gun muzzle, the JB-6e junction box that digitizes the Doppler signal, and the TestCenter 7 processing software running on a standard desktop PC. The radar is compact, light and fully sealed, and is normally installed in a firing corridor with the acquisition chain in an adjacent control room or protected bunker. Figure 1 shows a typical deployment.

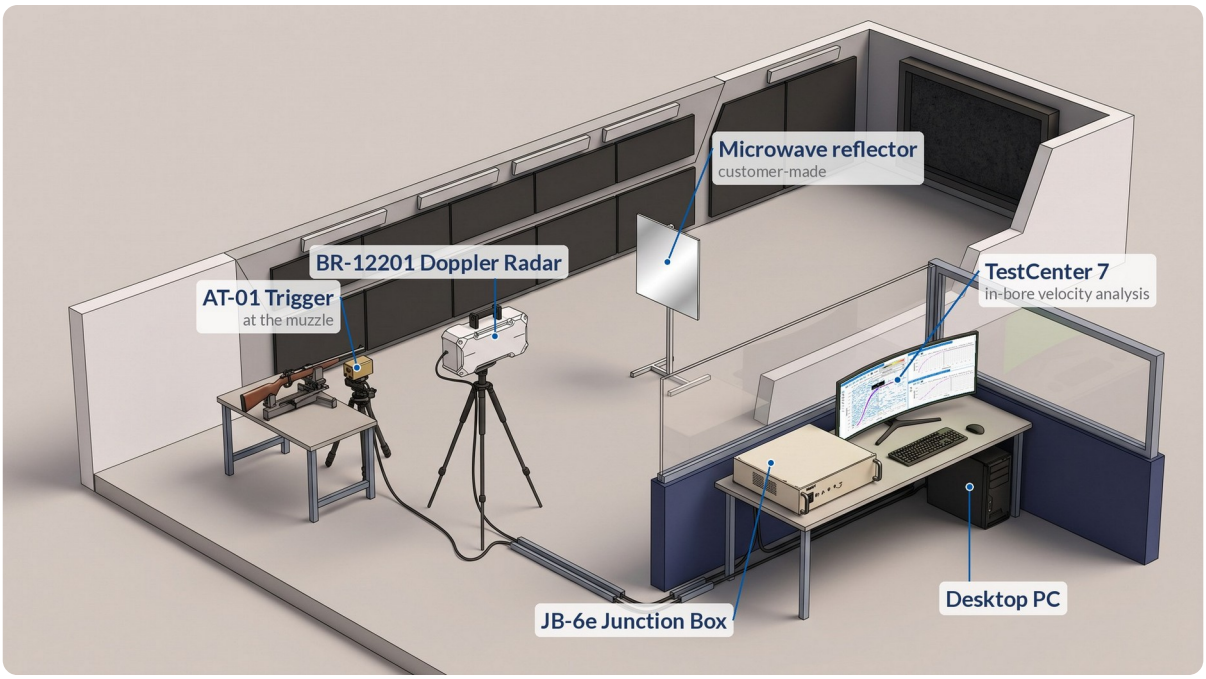


Figure 1 – Typical set-up of a BR-12201 radar system, Configuration A.

The measurement sequence is fully automatic:

- **The radar beam** is directed onto a reflector placed downrange; the reflector returns the microwave energy along the bore axis and into the barrel, where it illuminates the projectile as it travels up the bore.
- **The weapon** is fired and the muzzle trigger instantly provides the precise time-zero reference for the shot.
- **The projectile is measured continuously** as it accelerates along the bore; muzzle velocity is read immediately at barrel exit, provided the reflector is positioned so that it can be read.
- **The JB-6e junction box** digitizes the radar signal with 16-bit resolution and streams it over Ethernet to the acquisition computer; recording time is virtually unlimited on a high-performance network.
- **TestCenter 7** processes the signal: in-bore velocity against time and against travel inside the barrel, acceleration, muzzle velocity and full shot statistics.

Choice of trigger. The AT-01 acoustic trigger senses the muzzle blast, and the OT-01 optical trigger senses the muzzle flash. Both connect to the same trigger input and only the connecting cable differs, so a single acquisition set-up can use either. One trigger is used at a time, and the operator selects the one best suited to each firing position. The AT-02 trigger is also available for low-noise and subsonic shots, such as suppressed weapons, air rifles, quiet ammunition and subsonic ammunition.



AT-01 acoustic trigger (left) and OT-01 optical trigger (right).

3. BR-12201 Doppler Radar

The BR-12201 uses a circular waveguide antenna operating in continuous wave at 122.500 GHz, with a 4.3° × 5.3° beam and 30 dBi of gain. The transmitter is a Gunn diode source delivering 5 mW (7 dBm), and the receiver provides the sensitivity required to detect the very small radar cross-section presented by a small-calibre projectile inside a barrel. Velocity coverage is 30 to 1 550 m/s with a measurement precision of 0.1 %.

The radar is housed in a precision-machined, fully sealed aluminium enclosure with a carrying handle, and is supplied with its signal module permanently attached. It is light enough to be installed and aligned on a standard tripod in the confined space of a firing corridor, and is powered directly from the AC mains in a 115 VAC 60 Hz or a 230 VAC 50 Hz version, operating from 0 °C to +40 °C.



BR-12201 Doppler radar – 122.500 GHz in-bore antenna

3.1 In-bore measurement and installation

Once the microwave energy has entered the barrel it propagates as a guided wave, and its power no longer falls off with distance the way it does in free space. There is therefore no range-versus-calibre table for the BR-12201: what governs the measurement is a minimum bore diameter, not a maximum range. In-bore measurement is possible from 5.56 mm upwards, and down to 4.7 mm with additional mode correction. The measurement covers the whole in-bore travel, and muzzle velocity is read immediately at barrel exit provided the reflector is positioned so that it can be read. Figure 2 illustrates the principle.

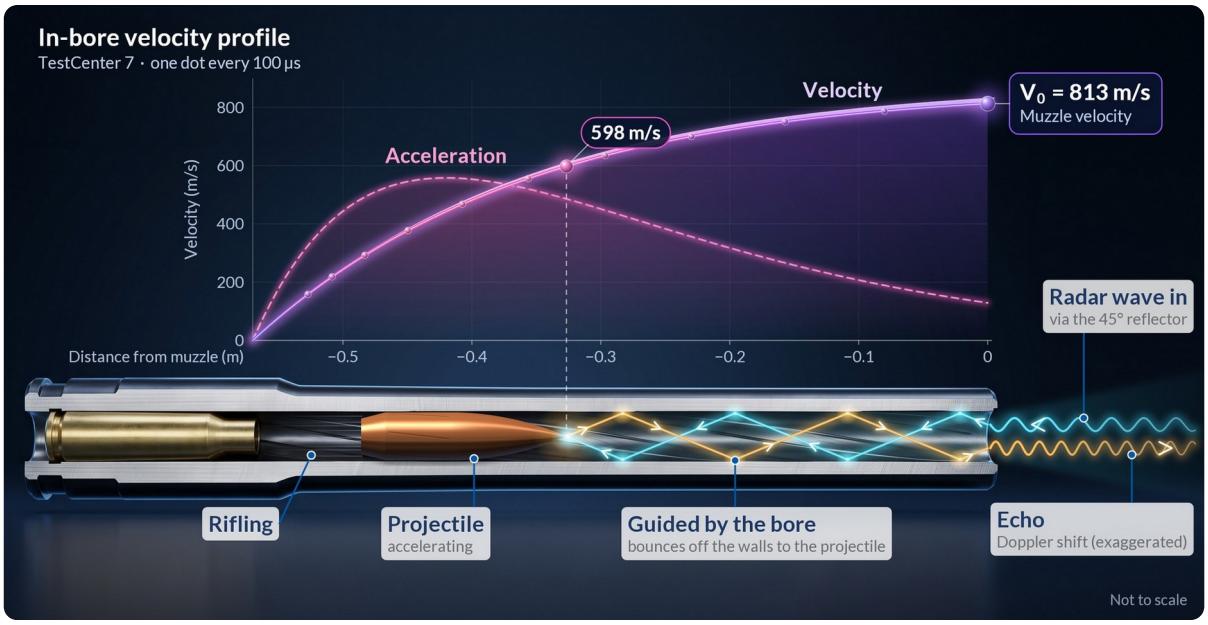


Figure 2 – In-bore measurement principle: the radar wave enters at the muzzle and is guided by the bore, bouncing off the walls to the projectile; the Doppler-shifted echo returns along the same path. TestCenter 7 converts the Doppler frequency into velocity and acceleration along the whole travel, up to the muzzle velocity V0 (illustrative values, not to scale).

The energy is directed into the barrel by a reflector placed in front of the muzzle, typically at five metres or less. The reflector is made by the customer to suit the installation and the test being performed: any microwave-reflective material is suitable – aluminium sheet, aluminium foil or steel. Because the reflector stands in the line of fire it will be damaged by firing, so an easily replaceable material and mounting are strongly recommended.

Two installation configurations are used, and they are equally valid; the choice depends on the layout of the range. In Configuration A (Figure 1) the radar is installed near the weapon and looks downrange at a reflector set perpendicular to the line of fire. In Configuration B (Figure 3) the radar is offset from the line of fire and a reflector set at 45° near the target folds the beam onto the bore axis.

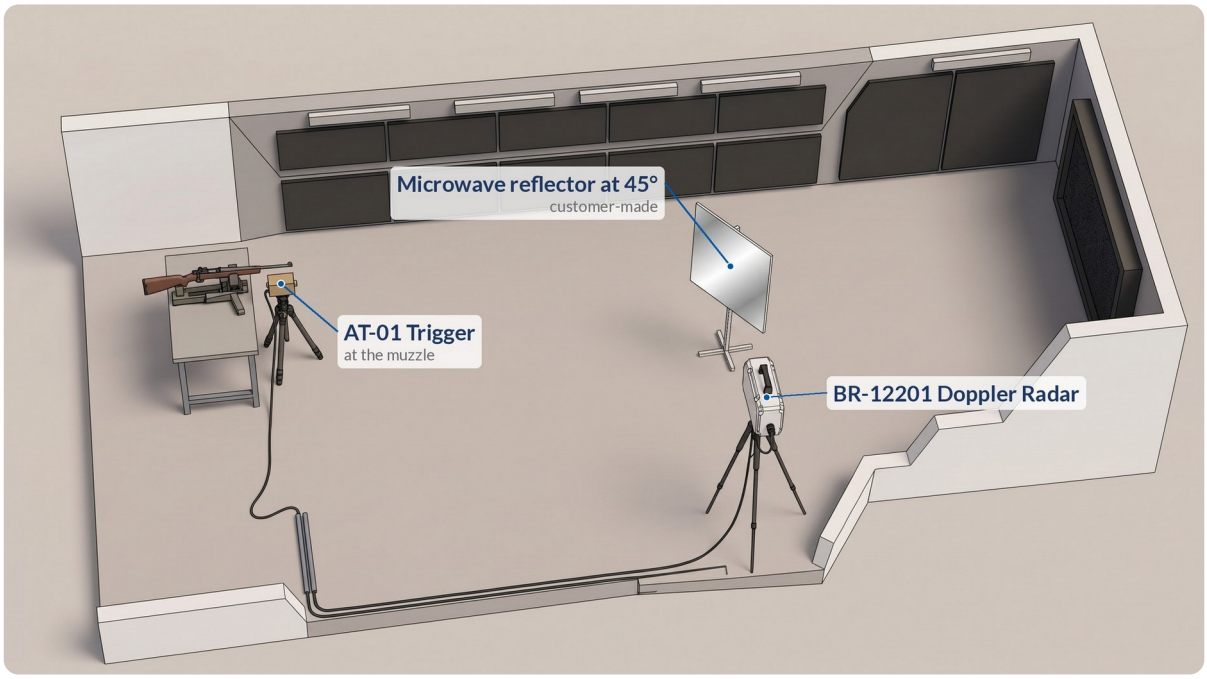


Figure 3 – Typical set-up of a BR-12201 radar system, Configuration B.

The AT-01 acoustic trigger is a required part of the chain. An in-bore record is only meaningful when the Doppler signal is precisely synchronized with the shot, and the AT-01, installed at the muzzle, provides that time-zero reference.

3.2 Technical specifications

Antenna gain	30 dBi
Antenna type	Circular waveguide
Beamwidth	4.3° × 5.3°
Polarization	Circular
Transmitter output power	5 mW (7 dBm)
Transmitter source	Gunn oscillator, CW
Modulation	None
Frequency	122.5 GHz (nominal)
System precision	± 0.1 %
Data acquisition	JB-6e junction box – 16-bit, Ethernet output
Receiver noise figure	10 dB
Radial velocity coverage	30 – 1 550 m/s
Minimum calibre	5.56 mm; 4.7 mm with additional mode correction
Operating temperature	0 °C to +40 °C
Storage temperature	-20 °C to +50 °C
Humidity	0 % to 100 % relative humidity, operating and storage (sealed enclosure)
Power supply	115 VAC 60 Hz 1.0 A or 230 VAC 50 Hz 0.5 A
Enclosure	Precision-machined, fully sealed aluminium, with carrying handle
Dimensions (radar)	33.7 cm (L) × 8.4 cm (W) × 17.6 cm (H)
Dimensions (power supply)	20 cm × 15 cm × 6 cm
Weight	6.4 kg
Approvals	—

3.3 Applications

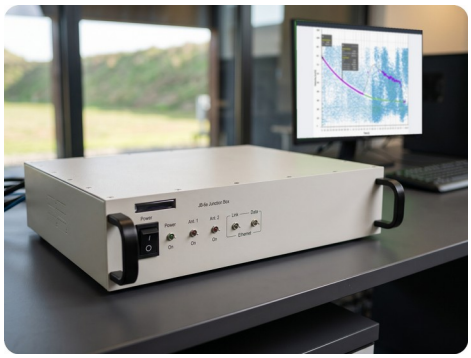
The BR-12201 gives direct experimental access to the interior ballistic phase of small-calibre weapons, where combustion, friction and projectile behaviour determine everything that happens after the muzzle. Typical applications include in-bore velocity measurement for small calibres; the study of internal combustion and of friction inside the barrel; work on extending barrel life through optimization; precise characterization of how internal variables change; and optimizing the compatibility of barrel, combustion and projectile for high-end small-calibre designs.

Why 122.500 GHz: the measurement is only possible because of the wavelength. At 122.500 GHz the wavelength is about 2.4 mm, roughly ten times shorter than that of an X-band radar. This is what allows the energy to propagate inside a small-calibre bore and the projectile to be resolved while it is still in the barrel, and it is what gives the velocity record the resolution needed to see the acceleration in detail rather than a single average figure.

4. JB-6e Junction Box – Data Acquisition

The JB-6e junction box is the data-acquisition heart of the system. Installed next to the acquisition computer, it conditions and digitizes the radar signal and communicates with TestCenter over a standard Ethernet link.

This separation is a deliberate design choice: by keeping the acquisition out of the radar head, the radar itself remains as robust and simple as possible, maximizing its operational availability – in contrast with competitor systems that integrate the acquisition inside the radar head.



JB-6e Junction Box

- **16-bit** analog-to-digital converters with integral filtering.
- **Dual antenna inputs** – two radars can be connected and acquired by the same unit.
- **100 Mb/s Ethernet** connectivity to the acquisition computer.
- **Analog trigger input and BNC trigger output** – the input accepts an Infinition trigger (AT-01, OT-01 or AT-02) or, with the optional BNC adapter, an external TTL trigger signal supplied by the range; the TTL output triggers other range instrumentation – or a second measurement system – on the same event.
- **Velocity acquisition coverage** from 30 m/s up to 10 000 m/s with X-band radars, 5 000 m/s with Ka-band radars and 1 550 m/s with the 122.5 GHz BR-12201.
- **Virtually unlimited recording time** on a high-performance network – the recording time depends on the network transmission speed, the sampling frequency and the internal FIFO memory of the JB-6e.

Two radars, one workstation. The second acquisition channel is delivered with every JB-6e and simply remains unused until a second radar is connected. Two radars are then acquired together, on the same time base, under a single TestCenter 7 workstation – a second radar covering a different firing position, or two radars on the same trajectory, one at the muzzle and one downrange. Adding the second radar requires no change to the acquisition hardware, to the software or to the operating procedure. Infinition supplies the two radars on distinct operating frequencies, so that they operate side by side without mutual interference.

5. TestCenter 7 – Radar Signal Processing Software

TestCenter 7 (released in 2024) is the latest generation of Infinition's Doppler processing software and the productivity benchmark of the industry. It runs on Windows 10 and 11, supports every Infinition radar, is compatible with the JB-6e junction box, and opens TestCenter 6.3.x files.



Figure 4 – TestCenter 7 on a wide-screen display, in-bore analysis of a 6.5 mm rifle shot: Doppler spectrogram with the in-bore acceleration track and the automatic V0 cursor at muzzle exit (813.15 m/s), velocity against travel inside the barrel, and velocity against time. The complete acceleration history – from first movement to muzzle exit – is captured in a single record.

5.1 What sets TestCenter 7 apart

- **New user interface** – a modern ribbon interface with dockable windows and simplified dialogs; the complete workflow (acquisition, spectrogram, velocity, drag) fits on a single ultrawide display, as shown in Figure 4.
- **Dynamic graphic engine** using 3D acceleration, with layer management and dynamic display: results are viewed and manipulated fluidly even on very large data sets. You can act directly on the graphs – a single click adds or optimizes measurement cursors right on screen.
- **Automatic analysis** – V0 and Vx measurements, track detection and burst tracking are fully automatic; a complete shot analysis takes seconds.
- **Project and series management** – a complete Project Manager including series and shot management: information is filed as the trials are performed, so you always know exactly where you stand in the current project during a firing campaign. Compare tracks across a series and get live statistics (average, extreme spread, standard deviation) as shots accumulate.
- **Batch processing** – modify analysis parameters and apply them to an entire series in a single operation, to uniformize results quickly and efficiently, with instant statistics update.
- **Reporting** – export every result table and curve to CSV, and copy any graph in one click for fast sharing of information. CSV is an open format, read by any analysis, reporting or database software, so results can be merged with data from other range instrumentation – no proprietary format and no dedicated import tool.

5.2 Ballistic analysis capabilities

On every shot, TestCenter 7 provides:

- **Velocity, distance and acceleration** – velocity vs time, velocity vs distance (derived using Integrated Velocity Ranging), distance vs time, acceleration vs time and acceleration vs distance; every curve and its underlying values are exportable to CSV.
- **Spectrogram** – the full Doppler signal is displayed as a velocity/time spectrogram. The automatic tracker locks on the projectile and measurement cursors (V0, V500, V1000 or any custom distance) are placed automatically, with velocity, distance and time reported for each.
- **Drag analysis (Cd vs Mach)** – available with the Advanced version of TestCenter 7, which includes the drag analysis module: measured drag coefficient as a function of Mach number, computed through the transonic zone, with trajectory prediction based on PM or MPM ballistic models. This measured-drag capability is a decisive advantage for ammunition characterization and acceptance testing.
- **Burst and rate of fire** – automatic tracking of every round of a burst, with the rate of fire and per-round statistics, and velocity tracking on multiple simultaneous projectiles.
- **In-bore measurement** – velocity and acceleration of the projectile along its travel inside the barrel, up to muzzle exit.

6. Scope of Supply and Support

6.1 Standard configuration – 1 complete set

The BR-12201 system is supplied as a complete, ready-to-operate set. A typical complete set includes:

- **BR-12201 Doppler radar antenna** – 115 VAC 60 Hz or 230 VAC 50 Hz version, with its permanently attached signal module and transit case.
- **JB-6e junction box** – data acquisition, Ethernet connection to the computer.
- **TestCenter 7 software license** – radar signal processing and ballistic analysis.
- **AT-01 acoustic trigger** – installed near the gun muzzle, with trigger cable.
- **Antenna cables, tripod and accessories** – everything required for deployment.
- **User documentation** – operation and analysis manuals.

Available options: OT-01 optical trigger, AT-02 trigger for low-noise and subsonic shots.

The reflector is not supplied with the system: it is made by the customer from microwave-reflective material to suit the installation, and should be treated as a consumable. Infinition also offers a complete range of Doppler radars for muzzle velocity and free-flight trajectory measurement.

6.2 Acquisition computer

TestCenter 7 runs on a standard desktop PC with the following minimum configuration: Windows 10 and 11, Intel Core i5 processor or better, 16 GB RAM, SSD drive and Ethernet port. An ultrawide display is recommended to take full advantage of the TestCenter 7 workspace shown in Figure 4.

6.3 Calibration and service

Calibration is supported directly by the manufacturer. The recommended approach is to return the equipment to Infinition's laboratory in Canada for a complete verification; the system is shipped back fully functional with its calibration certificate. Combined with our fast, personalized customer support, this keeps your system measuring – and your teams up and running.

7. Why Infinition

Infinition is a Canadian company in operation for more than 30 years, with a reputation proven around the world by the most reputable clients in the industry.

- **A complete radar range** – from in-bore measurement at 122.5 GHz and Ka-band laboratory radars to X-band radars for small arms, medium calibres and artillery, Infinition covers every calibre and every range with one family of instruments.
- **Proven reliability** – Infinition radars are extensively field-tested and recognized for a reliability that keeps our customers measuring, campaign after campaign.
- **Productivity** – TestCenter 7 automates the complete analysis workflow; results that used to require manual processing are produced in seconds, by any trained operator.
- **Investment protection** – all Infinition radars share TestCenter 7, TestCenter 6.3.x files can be opened, and a system grows with your needs: a second radar on the same JB-6e, a TH-1000 tracking head or optional analysis modules.
- **Single-source support** – Infinition designs and manufactures the radar, the acquisition hardware and the software in-house, and provides installation, on-site training and calibration services worldwide.

8. Contact

Request a quotation, a demonstration or technical information

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