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BR-1001 Doppler Radar
Operating Manual

Art, Science & Technology Infinition Inc.		3630 Jean Talon Trois-Rivieres Quebec, Canada G8Y 2G7		REQUIREMENT / SPECIFICATION BR-1001 Doppler Radar Operating Manual	
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PREPARED BY:	Stephan Boucher	01/15/07		DATE OF ISSUE:	REV: 1
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BR-1001 CW Doppler Radar
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1 Introduction

The Doppler radar systems produced by Infinition Inc. are used for velocity measurements for ballistic and non ballistic test on moving targets.

The velocity information is obtained by means of the Doppler principle which states that reflected radar signal from a moving object will be frequency-shifted by a valud f_d relative to the transmitter frequency f_0, and that the frequency shift will be proportional to the radial velocity v of the object relative to the antenna. The mathematical relation is:

$$f_d = \frac{2 \times f_0}{c} \times v$$ where c is the speed of light in the air.

Equation 1. Doppler equation

The Doppler signal, which is output by the radar in analog form, contains a frequency (velocity) component for each moving target located in the radar beam coverage. The radar antenna must be used in conjunction with a radar signal processor, which basically digitized the Doppler signal and extract the frequency (velocity) information for each target using digital signal processing techniques.

The CW radar basically consists of transmitter and a receiver. The transmitter and the transmitting antenna produces a microwave signal at 10.525GHz (nominal) that is used to illuminate the moving targets. The receiver, together with the receiving antenna, detects the scattered energy in the direction of the antenna unit from the targets. The receiver implements a mixing process that takes a sample of the transmitted signal and mixes it with the received signal to obtain the frequency difference between both signals. This is the Doppler signal.

The radar electronics are self-contained in a cast magnesium enclosure to provide protection.

2 Radar Characteristics

The table below lists certain characteristics of the Doppler radar for reference purposes.

Parameter	Value
Power Requirement	- 115 Vac, 60Hz, 1.0 Amps (U.S. version), or - 230 Vac, 50Hz, 0.5 Amps (European version)
Physical dimension - Length - Width - Height - Weight	 27cm (10.63”) 13cm (5.12”) 51cm (20.08”) 14kg (30.86lb)
Transmitter - Radiated Power - Duty Cycle - Modulation - Frequency (nominal) - Phase Noise (typical) - Frequency Stability	 Low: 23 dBm, High: 33 dBm (selector switch) Continuous (100%) None 10.525 GHz -80 dBc/Hz @ 10 kHz +/- 15 ppm
Antenna (Transmit / Receive) - Size - Polarization - Gain - Beamwidth - Cross Polarization - Power Rating - Type	 14.7” x 14.7” x 0.4” Vertical (Horizontal optional) 23 dB nominal 9 deg x 12 deg > 20dB 10 Watts Flat panel, microstrip
Receiver - Noise Figure - RF Frequency - RF Bandwidth - Doppler Bandwidth - Clutter Rejection - Radial Velocity Coverage - Maximum (operating) Feedthru Level - Typical Transmitter Feedthru Level (@ 33 dBm output) - Transmitter / Receiver Isolation	 3 dB X-Band 500 MHz 2 – 210 kHz > 100 dB 30 – 3000 m/s -8 dBm < -32 dBm > 65 dB
Warning Device - Output Voltage - Max. output current	 12Vdc 2 Amps (fuse protected)

Table 1. Radar characteristics

3 Radar Simplified Block Diagram

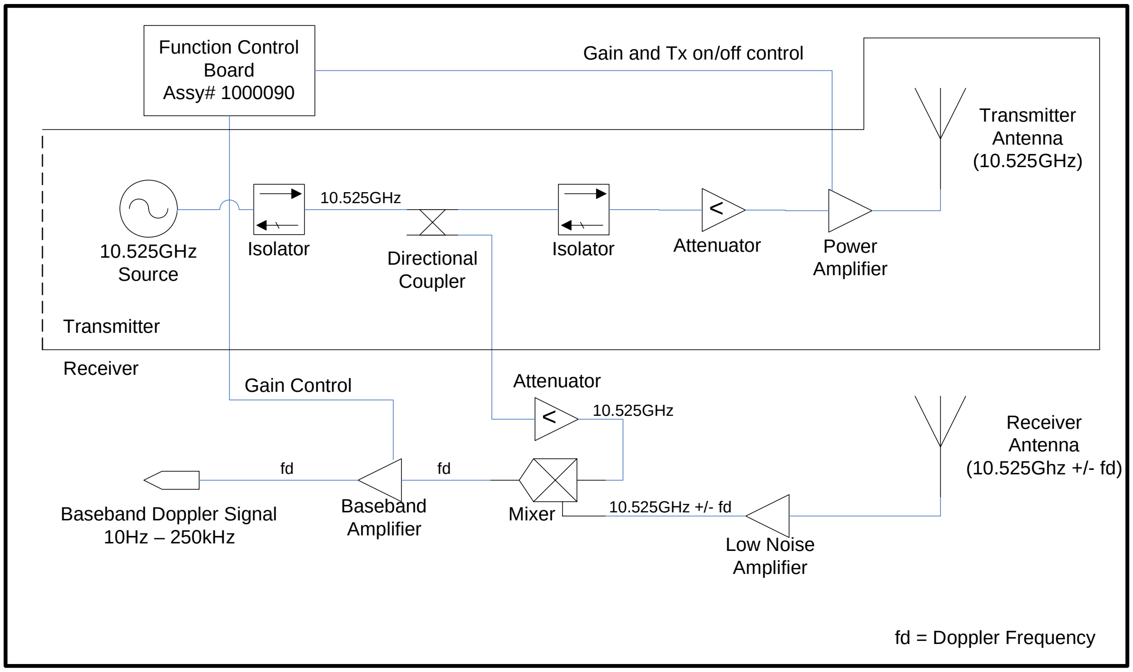

Figure 1. Radar simplified block diagram

4 Transmitter

4.1 General

The transmitter generates the microwave energy that is used to illuminate the target. The low-level, highly stable frequency is generated by the oscillator and is amplified by the power amplifier to the required level and then fed into the transmitting antenna.

4.2 Microwave Assembly

The transmitter consists of:

- Transmitter oscillator
- Power amplifier (PA)
- Transmitter antenna

Connections between the microwave components are done using semi-rigid, conformable coaxial cables or SMA joints. Proper tork is applied on the SMA connectors using a tork-wrench.

4.2.1 Oscillator

The transmitter oscillator is a phase-locked dielectric resonant oscillator (PLDRO) operating at 10.525GHz nominally. The PLDRO output is fed into a ferrite isolator to improve the actual VSWR of the oscillator component and also for protection. The frequency of the oscillator is preset by the manufacturer and cannot be adjusted in the field. When the antenna main power is switched on, the PLDRO is energized and ready to drive the PA and the receiver.

The signal is then split into two signals with a 10dB directional coupler. The primary output of the coupler serves as the input for the PA. The coupled output is used to provide a signal sample to the LO input of the mixer in the receiver.
A second isolator is used between the primary output of the coupler for additional protection against poor VSWR. Before being fed to the PA, the signal is attenuated using a series of inline attenuators in order to match the signal level to the PA input characteristics.

4.2.2 Power Amplifier

The generated low level microwave signal is amplified to the desired level using the power amplifier (PA). An isolator is installed at the output of the PA to protect it against the RF signal that could be reflected back from obstacles located in the beam. The output power level is selectable by a switch on the radar panel and is 2 Watts (33 dBm) at the high output setting, or 0.2 Watt (23 dBm) at low output setting. The PA is a gain control amplifier providing between 28 and 32 dB of gain and between 10 and 15 dB of gain adjustment using an integral electronic attenuator. The two output levels supported by the BR-1001 radar are obtained by applying the appropriate control voltage to the attenuator port on the PA, which is generated by the Function Control board. It allows the user to select low transmit power to prevent saturating the transmitter when using the radar for short range measurement.

A switch on the radar front panel, which controls the enable pin of the PA internal voltage regulator, is used to switch the transmitter on and off.

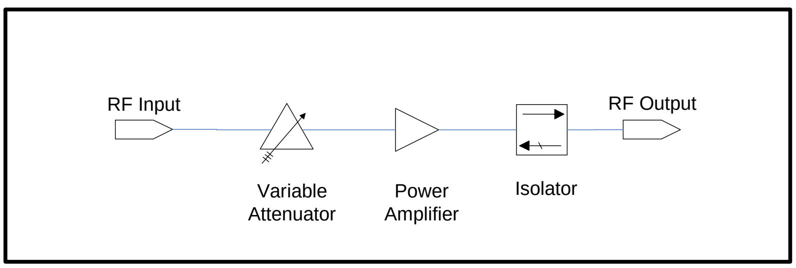

Figure 2. Power Amplifier Diagram

The PA is powered using a switch mode power supply. It draws about 2 amperes of current at 12 Vdc.

4.2.3 Transmitting Antenna

The transmitting antenna is a microstrip based flat panel antenna mounted in an aluminum housing and protected by a plastic radome. The transmitting and the receiving antennas are identical.

Flat panel antennas are less sensitive to microphony and vibration.

5 Receiver

5.1 General

The receiver is used to extract the Doppler frequency (velocity) components from the microwave energy reflected from objects located in the transmitter beam. This energy comes from targets having radial speed and from fixed objects. The receiver discriminates between the two and only the moving targets are extracted. The resulting information is an analog signal containing as many Doppler frequency components as there are moving targets in the radar beam.

5.2 Microwave Assembly

The receiver consists of:

- Receiving antenna
- Low noise amplifier front-end
- Baseband down-converter (mixer)
- Baseband amplifier and signal conditioning

Connections between the microwave components are done using semi-rigid, conformable coaxial cables, flexible coaxial cables or SMA joints. Proper tork is applied on the SMA connectors using a tork-wrench.

5.2.1 Receiving Antenna

The receiving antenna is identical in construction to the transmitting antenna. It receives the signal reflected from the moving targets and feeds it to the receiver electronics for amplification and baseband down-conversion.

5.2.2 Low Noise Amplifier Front-End

Only a small fraction of the transmitted signal is being reflected back from the target towards the receiver antenna. That weak signal must be amplified before being down-converted to baseband. This is done by using a very Low Noise microwave Amplifier (LNA), which serves as a front-end to the baseband down-converter mixer. The LNA offers a very low noise figure of less than 3 dB and provides a gain of 20 dB. The mixer having a poor noise figure of about 8 dB, the use of a LNA in combination with the mixer reduces the overall noise figure of the receiver. In addition, the LNA has an integral limiter that protects the amplifier against strong returns that can be generated by close or large targets as well as ground clutter.

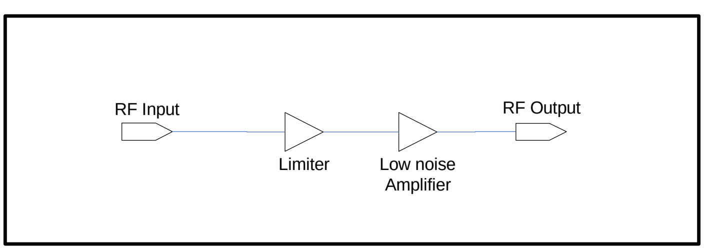

Figure 3. Low Noise Amplifier Front-End Diagram

5.2.3 Baseband Down-converter Mixer

The output signal of the LNA is fed into the RF input of a double balanced mixer where it is heterodyned with a sample of the transmitted signal. The mixing process down-converts the received signal to baseband and produces the Doppler signal, which is also referred to as the video or the IF signal. The output of the mixer is a very low amplitude signal. The LO signal level is 10-13dBm.

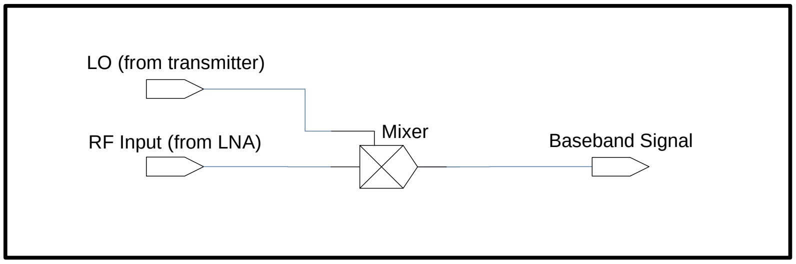

Figure 4. Down-converter mixer

5.2.4 Baseband Amplifier

The Doppler bandwidth is 210 kHz, which corresponds to a maximum detectable velocity of 3000 m/s.

The bandwidth of the receiver front-end is 500 MHz, which is much larger than the Doppler bandwidth. The frequency response is reduced to 210 kHz by filtering the video signal with low-pass filters. Limiting the bandwidth offers several advantages. It reduces the susceptibility of the radar to external interferences. It also allows more than one radar to be used in close proximity without interfering each other, as long as their transmitter frequencies are slightly different. A difference of 10 MHz is normally sufficient. In addition, low frequency information corresponding to ground clutter is suppressed by using high-pass filters. Frequencies below 2 kHz, which correspond to velocities below 30 m/s, are filtered out to provide sufficient ground clutter suppression (zero Doppler target suppression). This band limiting process is entirely done at baseband on the video signal by the baseband amplifier.

The baseband amplifier is a very low noise amplifier that provides up to 90 dB of gain (factory adjustable). Its main purpose is to amplify the weak signal that comes out of the mixer to a more suitable voltage level for the Doppler processor. The mixer output is in the microvolt range and the amplifier brings it to +/- 5 Volts with almost no addition of noise. The noise figure of this amplifier is better than 5 dB. The amplifier gain is factory tuned to roughly 70 dB. The second role of the baseband amplifier circuit is to condition the signal before it is output. This implies a conversion from single-ended to floating differential output, which is required to preserve the signal integrity when it is sent over long cables.

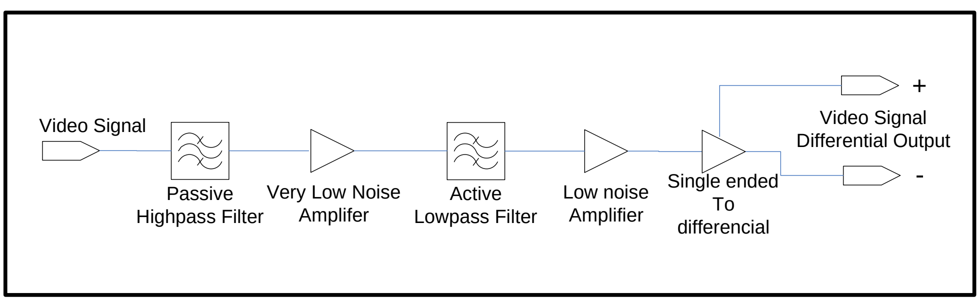

Figure 5. Baseband Amplifier Diagram

Because the receiver is dealing with very weak RF signals, the power supply used to power the microwave components must be of low noise type. This is achieved by using a linear power.

6 Function Control Board (assy# 1000090)

The Function Control Board (FCB) is used to provide the control voltages to the receiver and the transmitter. It also provides an interface for the control switches located on the radar control panel. It is used to implement the following functions:

- Transmitter power level selection.
- Transmitter on/off control.
- Supply voltage distribution for the receiver components and the PLDRO.
- Gain control voltages for the baseband IF amplifier.

6.1 Transmitter Power Level Selection

The transmitter power level is achieved by providing the appropriate voltage level to the transmitter power amplifier. Since two power levels are supported, high and low, two different voltages need to be generated based on the corresponding front panel selector switch. The voltage values are tuned using two potentiometers located on the Function Control Board in order to obtain the desired power level at the output of the transmitter power amplifier both power level settings. See tuning procedure document for more details.

6.2 Transmitter On/Off Control

The power amplifier used in the transmitter uses an internal voltage regulator that can be switched on and off with a TTL signal, enabling or disabling the amplifier. This TTL signal is generated by the Function Control board based on the corresponding front panel switch position.

6.3 Supply voltage distribution

The Function Control Board is used as a distribution point for the antenna linear power supply. All the supply voltages required the microwave and baseband components in the receiver are generated by this board.

6.4 Baseband IF Amplifier Gain Control

The baseband amplifier has two high gain and low noise amplifier used in series. The gain for each amplifier is independently adjustable using analog control signals. An analog voltage level is generated by the Function Control Board for each amplifier and can be adjusted using two potentiometers. The gain is adjusted to get around 100 and 200mVdc of signal at the output with no moving target in front of the radar.

7 Power Supplies

The radar unit contains two distinct power supplies, one for the transmitter and one for the receiver.

The power amplifier in the transmitter draws about 2 amps of current at 12Vdc and it has its own power supply. It is a switching mode power supply capable to generate up to 6 amps of current. This power supply is also used to provide 12Vdc for the warning device and the current is limited to 2 amps using a fuse.

The receiver uses a linear power supply that generates 12Vdc for the PLDRO and the LNA, and +/-5Vdc for the IF amplifier.

A power line filter is used in conjunction with the supplies.

8 Antenna Radiation Pattern

The radiation pattern in azimuth and elevation of the antenna used in the radar unit are presented below:

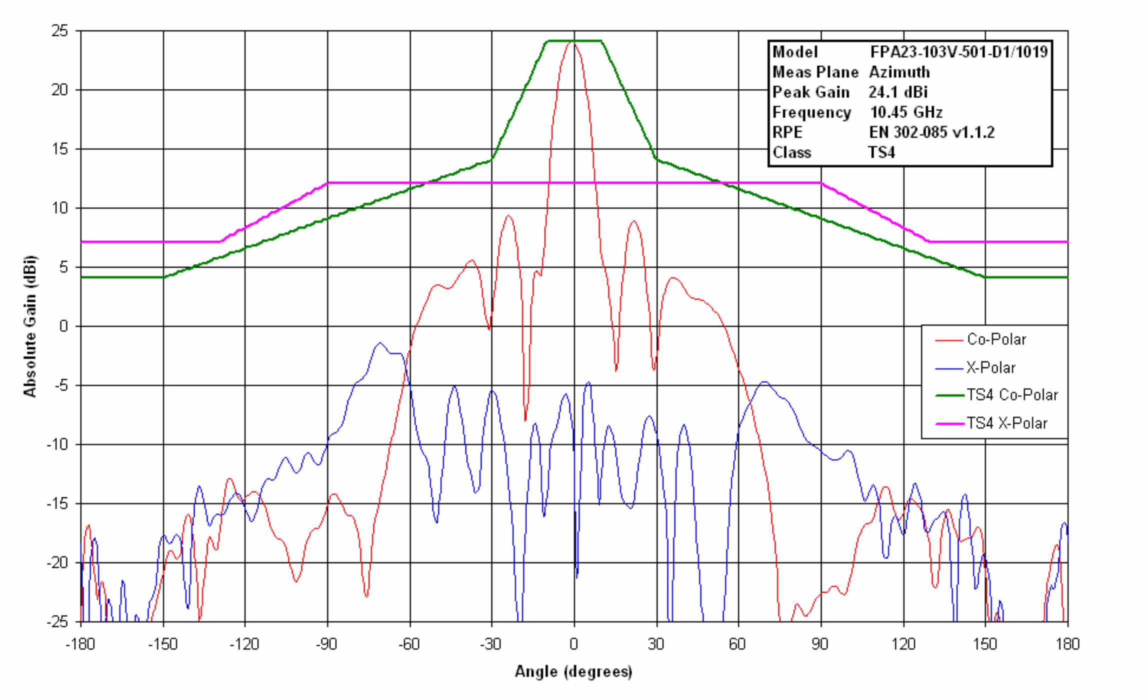

Figure 6. Radiation pattern in Azimuth

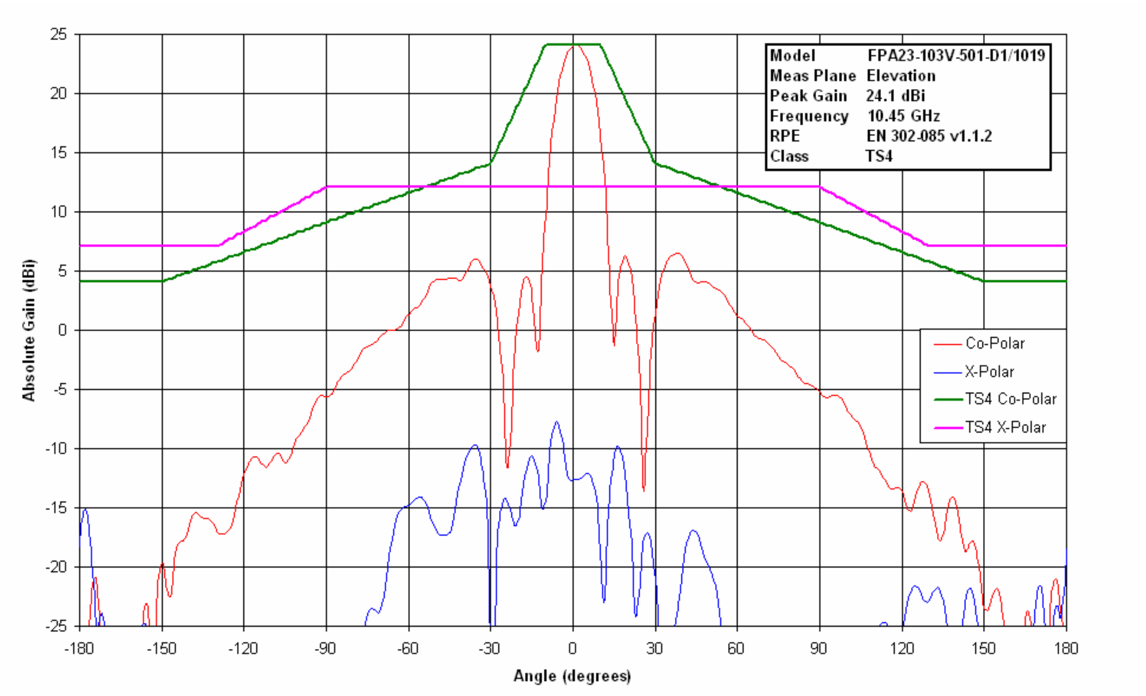

Figure 7. Radiation pattern in elevation

9 Front Panel Functions

The front panel provides basic function control to the user.

There is power switch that is used to switch the antenna on and off. A LED indicator also provides the status of the power switch.

There is another switch that is used to switch the transmitter on locally. It allows the user the enable the transmitter at the antenna without having to arm the radar system. This can be useful for maintenance purposes. A LED indicator displays the transmission status of the transmitter.

A third switch is used for the transmitter output power level selection. The selector switch can be set either to low or high output power. An LED indicator is illuminated when the transmitter is in high output power mode.

There is a power entry connector. A multi-pin circular connector is provided to get access to the radar Doppler signal and control. And finally, there is a connector that can be used to activate a transmission warning device.

10 Connector Pin-out

10.1 Signal Connector

Connector type: MS3124E16-8P

Pin	Description
A	Not Connected
B	Not Connected
C	Not Connected
D	Remote Make for Antenna Transmitter Control (+ 5 Vdc Output)
E	Make Return
F	Doppler Signal + (5 Vpp max.)
G	Doppler Signal - (5 Vpp max.)
H	Ground

Table 2. Signal connector pin-out

The pin D and E can be used as make circuit to control the transmitter remotely. When those two pins get connected together, this activates the transmitter. The pin D signal is 5 Vdc and the current is limited by a >1.5kOhm resistor.

The pin F and G are Doppler signal outputs. This is a differential signal that provides good immunity against environmental electrical noise it is connected to a processor having a differential input.

10.2 Warning Device Connector

Connector type: MS3124E12-3S

Pin	Description
A	+12Vdc (2 amps maximum, fuse protected)
B	n/c
C	Ground

Table 3. Warning device connector pin-out

This connector can be used to power an external warning indicator. The voltage on pin A is enabled when the transmitter is switched on.