V1.00

1. Introduction

The DF800 series microwave motion sensor modules are K-Band Bi-static Doppler transceiver front-end modules. These modules are designed for speed detection with direction of motion recognition and are suitable for traffic applications.

The module consists of Dielectric Resonator Oscillator (DRO), balanced mixers, patch antenna, built-in LNA for high sensitivity and a pre-amplifier (see Figure 1).

This Application Note highlights some important points for application with DF800 series.

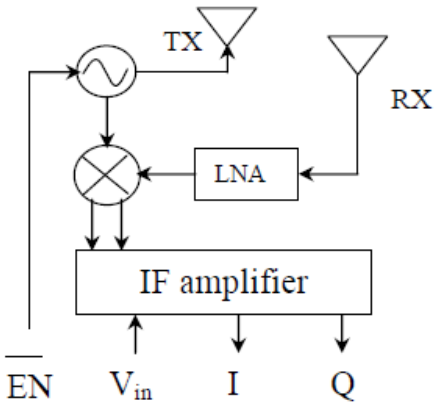


Figure 1: Block Diagram

2. User interface and mounting

6-way 2.54 mm pin header is used for user interface and the four mounting holes of M2.5 screw size are as shown in Figure 2.

Pin definition

1: $\overline{EN}$

2: V_{in}

3: GROUND

4: I

5: Q

6: *NOT IN USE*

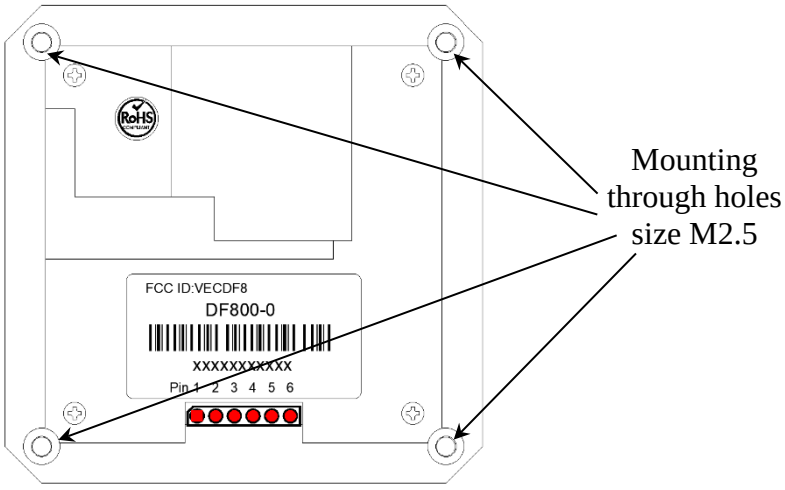


Figure 2: Pin definition and mounting holes

ST Engineering Electronics Ltd.
ST Engineering Hub, 1 Ang Mo Kio Electronics Park Road, #06-02,
Singapore 567710
Tel: (65) 6521 7888 Fax: (65) 6521 7801 Email: info@agilsense.com
Website: www.agilsense.com (*Regn. No.: 199103901W*)

3. Power Supply

There is a built-in voltage regulation in the DF800 series modules. As such, the performance of the DF800 series modules is not affected by variation of voltage supply as long as the supply is within the specification such as 2.7V, 3.3V and 5V.

4. Transmitting Frequency and EIRP

The transmitting frequencies (ISM band) and EIRP (Effective Isotropic Radiated Power) of various modules are factory-set and are not user-adjustable. Table 1 shows the EIRP and transmitting frequency of the DF800-0 module. For a complete list, kindly refer to DF series selection list.

Local radio communication authority regulates the use of transmitting devices. Though user license may be exempted, type approval of equipment or other regulation compliance may be required.

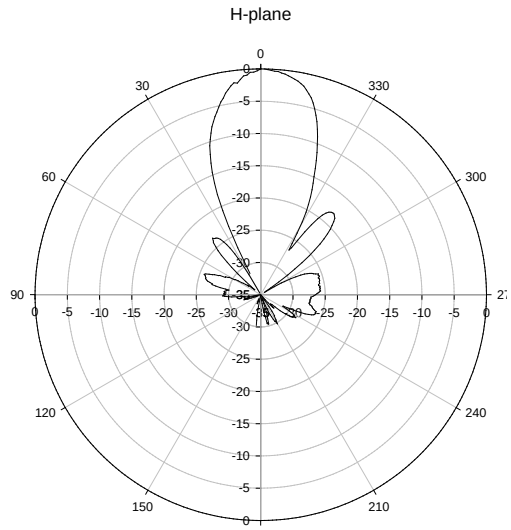
Model	EIRP	Centre Frequency
DF800-0	11.94 dBm	24.125 GHz

Table 1: Transmitting frequency for DF800-0

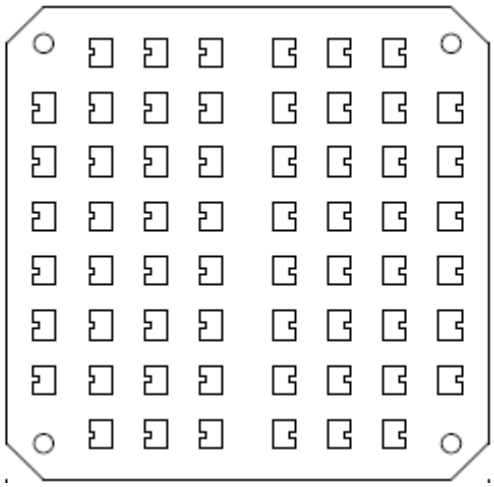
Please refer to Annex 1 for more information on transmitting signal.
The FCC and IC statement in Annex 2 and Annex 3 respectively, applies to DF800 series modules.

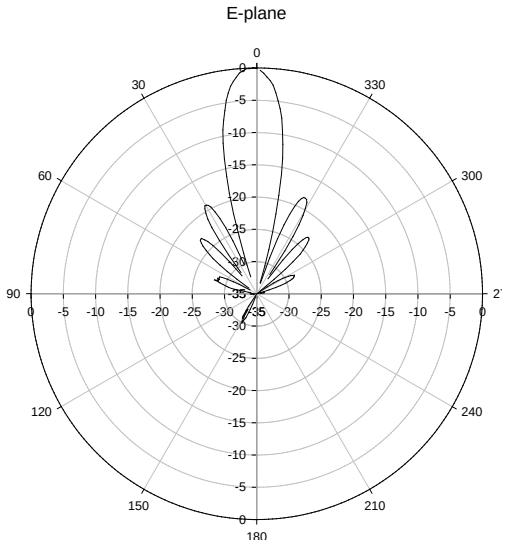
5. Radiation Pattern

The module to be mounted with the antenna patches facing to the desired detection zone. The user may vary the orientation of the module to get the best coverage. The radiation patterns of the antenna and their 3dB beam width are shown in below diagram.



Azimuth





Elevation

Figure 3: Beam pattern of DF100

6. IF amplifier gain and frequency response

The DF800 series transceiver modules come with a built-in two-stage IF amplifier. The amplifier is designed to provide low noise and hence, higher sensitivity. Besides, this amplifier acts as a buffer so that the performance of the module is not affected by the loading at the IF output. A loading of at least 1 kΩ is recommended at the IF output.

The frequency response of the amplifier of DF800-0 is shown in Figure 4. For DF800-0, the lower 3dB cut-off frequency is approximately 200 Hz, resulting in a speed cut-off of about 4.5 km/h. As human walking speed is typically below this cut-off, human detection is therefore masked by this module.

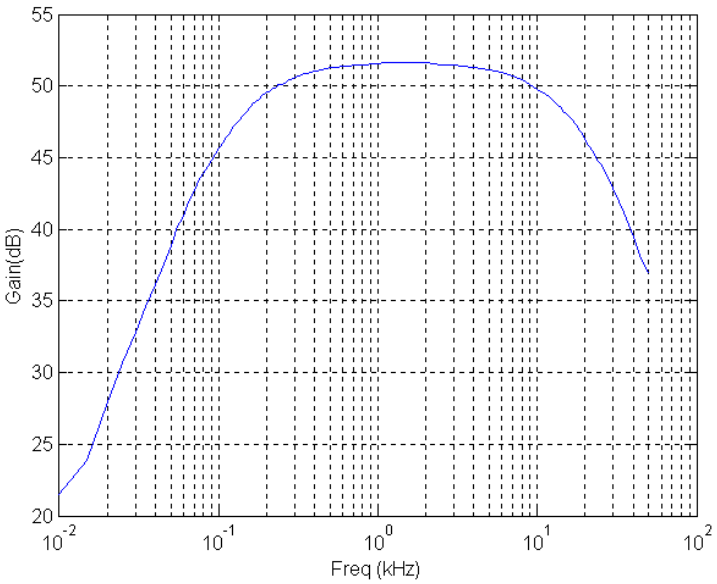


Figure 4: Frequency response of IF amplifier of DF800-0

7. IF output signals

Doppler shift - Doppler-shift signals of ideally 90^{o} phase difference between them appears at I & Q channels when movement is detected. These signals are pre-amplified by built-in IF amplifiers for better sensitivity and better isolation. The magnitude of the Doppler Shift after these amplifications is typically within 1V peak to peak. Frequency of Doppler shift is proportional to velocity of motion and is governed by equation shown in Annex 4.

The lagging/leading phase difference between I and Q signals provides information on the direction of motion (whether approaching or receding)

8. How far can the DF800 series module detect the moving target?

A frequently asked question is how far can DF module detect the moving object?

It depends on a number of factors, such as the power received by the module after reflection off the target, the sensitivity of the module itself (characterized by the noise figure of the module) and the environment noise.

Let us first take a look at the power received by the module after reflection off the target, which is governed by this formula.

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 r^4}$$

Where P_t is the power transmitted by the module,
G is the gain of the transmitting and receiving antennas, assuming same gain.
λ is the wavelength of the transmitted signal
σ is the radar cross section of the target
r is the distance between the module and the target.

The parameters P_t, G and λ are intrinsic to the modules and are part of the design consideration. However, σ is an external factor, which effectively refers to the portion of energy reflected by the target. The radar cross section of a target is defined by the size, the shape, the orientation and the make of the object.

The SNR (signal to noise ratio) needed for a 99.9% detection is 14dB and as such, it defines the minimum P_r for the module. However, if the environment noise is higher than the intrinsic noise of the module, the SNR will deteriorate and it will result in shorter detection range.

Another factor which may affect the detection distance is the way the signal is processed. The detection distance can be improved by
(1) Narrowing the bandwidth of the IF signal, which improves the SNR.
(2) Optimizing the dynamic range. The IF signal may be further amplified prior to signal processing for higher sensitivity but one has to ensure that this amplification does not distort the signal which will complicate the signal processing.

Typically, DF800-0 can detect a car at a distance of 500m.

9. Placing the module in enclosure

As the applications of DF800 series are mostly in traffic (outdoor), it is inevitable that the module needs to be housed in an enclosure. As such, it is important to ensure that the performance of the module is not significantly degraded by the presence of enclosure.

The recommended material for the enclosure is plastic (such as ABS), as microwave can penetrate through the material without significant loss. For comparison purpose, a metal results in full reflection while water results in high absorption of the microwave. It is therefore important not to use any metallic material as the enclosure.

It is recommended that the cover placed in front of the DF antenna is of flat panel, so that the beam width of the antenna is not significantly distorted. The thickness of the cover, h_1 and the spacing between the antenna and the cover, h_2 should be ideally half-wavelength of the microwave signal.

In this case, for DF800-0 series module whose transmission frequency is ~24GHz, the recommended h_1 and h_2 are 3-4mm and 6mm.

A half wavelength of a 24 GHz in the air is about 6mm. However, the half wavelength of the signal in other medium depends on the dielectric constant of the material. In the case of ABS which has a dielectric constant of between 2.5 to 3.5, the half wavelength of the signal is 3 – 4 mm.

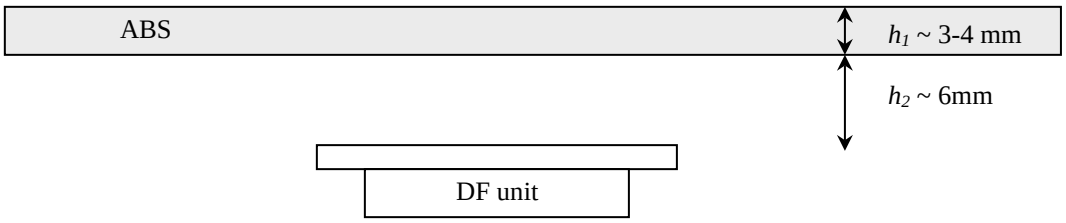


Figure 5: Recommended thickness and clearance for ABS placed in front of DF sensor

10. Using EN (pin 1)

EN (pin 1) can be used to control the oscillator. The internal voltage source is supplied to the oscillator via a PNP transistor switch. When EN is asserted LOW (GND), the switch is on and internal voltage is supplied to the oscillator, resulting in a transmission of 24GHz microwave signal. On the other hand, when it is driven HIGH (+3.3V or higher), the oscillator is de-activated. The current drawn from the EN pin is typically less than 1mA, and hence, it can be driven by TTL or CMOS as long as the voltage high is +3.3V or more.

This feature can be used to reduce power consumption by introducing pulse to this pin.

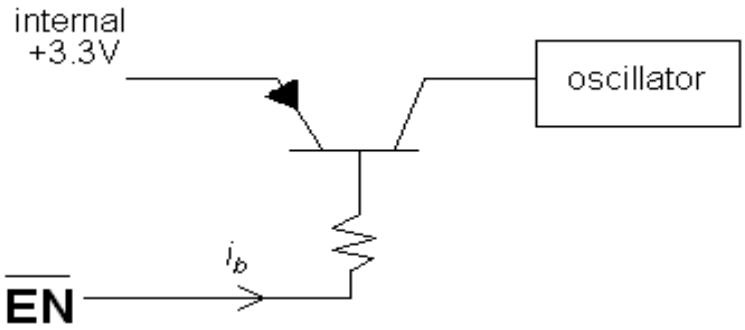


Figure 6: Internal circuit of EN function in DF sensor

A typical transient response at channel I or Q (will be called IF outputs) due to assertion of EN is illustrated in Figure **7**. When EN (green line) is driven LOW, the Doppler signal takes t_1 to start appearing

at the IF output (brown line) and the DC steady state is achieved after t_2. For the duration between t_1 and t_2, there are Doppler signals but the dynamic range is poorer as the steady state has not been achieved yet. If the dynamic range in this duration is not problem, speed can be measured after t_1. In general, we recommend that the speed measurement starts only after t_2. As such t_2 is defined as the settling time and this parameter is showed in selection list for DF series. For DF800-0, the typical values for t_1 and t_2 is approximately 4 msec and 10 msec, respectively.

The time, t_{on}, is the duration when the EN is low (which activates the DRO) whereas t_{off} is the duration when EN is high. The duty cycle is defined by $t_{on}/(t_{on}+t_{off})$ and the slow cycle frequency is defined as $1/(t_{on}+t_{off})$. For illustration purpose, in , the duty cycle is 50 % and the frequency is 20 Hz.

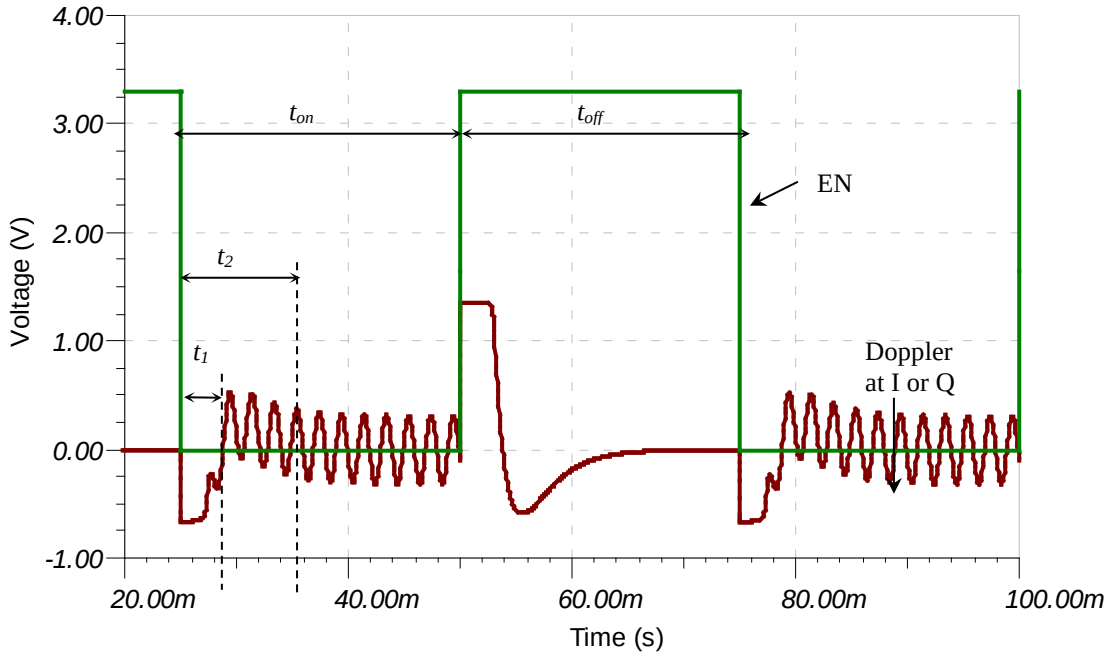


Figure 7: Typical transient response at the output of DF sensor

Some of the factors to consider in determining the values of t_{on} and t_{off} are power consumption, minimum speed to measure and update rate, as there are trade-off between these parameters. The smaller the duty cycle, the lower the power consumption. However, if t_{on} is too short, it will not be able to measure slow speed target. For example, in order to measure a target with speed of 5 km/h (~223 Hz Doppler), the t_{on} duration has to be at least 5msec + t_1 to accommodate one wavelength of Doppler. In usual practice, it is advisable to accommodate for more than one wavelength in the t_{on} window. On the other hand, if t_{off} is too long, the update rate for the speed detection is low.

11. Radiation Safety

Microwave radiation from the module is well below established safety standards for general public environment, like ANSI C95.1-1991 of USA and NRPB-G11 of United Kingdom.

12. Handling

The module has been fully tested to specifications. Opening, tightening or loosening the chassis may result in performance deterioration.
The module is an electrostatic sensitive device (ESD). Precautions shall be observed for handling and assembly.

13. Product Support

Please contact our product support engineers in the factory for technical assistance whenever necessary.

Product Support (Microwave Sensors)
Tel: (65) 6521 7888
Fax: (65) 6521 7801
E-mail: info@agilsense.com

Annex 1: Transmission of RF

1. Though same frequency is allocated in some countries, national regulations may specify different EIRP, spurious emission or other requirements.
2. ETS EN300 440 is the recommended harmonized standard for European Community, member country may adopt their own national regulation. The DF100 series transceivers meet the requirement of EN300 440
3. The DF800-0 model is designed to meet the FCC standard part 15.245 and is aimed for use in the America.
4. The regulations are subjected to change from time to time, please contact appropriate authorities for full and up-to-dated information.
5. Useful websites:

Agency	Website
The Code of Federal Regulations, USA	http://www.access.gpo.gov/cgi-bin/cfrassemble.cgi?title=199847
The European Radio Communication Office	http://www.ero.dk/
The Radio Communications Agency , UK	http://www.radio.gov.uk/
Federal Communications Commission	http://www.fcc.gov/

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Annex 2: Federal Communication Commission Interference Statement

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

FCC Caution: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

Radiation Exposure Statement:
This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.

This module is intended for OEM integrators only. Per FCC KDB 996369 D03 OEM Manual v01 guidance, the following conditions must be strictly followed when using this certified module:

KDB 996369 D03 OEM Manual v01 rule sections:

2.2 List of applicable FCC rules

This module has been tested for compliance to FCC Part 15

2.3 Summarize the specific operational use conditions

The module is tested for standalone mobile RF exposure use condition. Any other usage conditions such as co-location with other transmitter(s) or being used in a portable condition will need a separate reassessment through a class II permissive change application or new certification.

2.4 Limited module procedures

Not applicable.

2.5 Trace antenna designs

Not applicable.

2.6 RF exposure considerations

This equipment complies with FCC mobile radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of 20cm between the radiator & your body. If the module is installed in a portable host, a separate SAR evaluation is required to confirm compliance with relevant FCC portable RF exposure rules.

2.7 Antennas

The following antennas have been certified for use with this module; antennas of the same type with equal or lower gain may also be used with this module. The antenna must be installed such that 20 cm can be maintained between the antenna and users.

Antenna Type	Microstrip Patch Antenna
Antenna connector	N/A

2.8 Label and compliance information

The final end product must be labeled in a visible area with the following: “Contains FCC ID: VECDF8”. The grantee's FCC ID can be used only when all FCC compliance requirements are met.

2.9 Information on test modes and additional testing requirements

This transmitter is tested in a standalone mobile RF exposure condition and any co-located or simultaneous transmission with other transmitter(s) or portable use will require a separate class II permissive change re-evaluation or new certification.

2.10 Additional testing, Part 15 Subpart B disclaimer

This transmitter module is tested as a subsystem and its certification does not cover the FCC Part 15 Subpart B (unintentional radiator) rule requirement applicable to the final host. The final host will still need to be reassessed for compliance to this portion of rule requirements if applicable.

As long as all conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

IMPORTANT NOTE: In the event that these conditions can not be met (for example certain laptop configurations or co-location with another transmitter), then the FCC authorization is no longer considered valid and the FCC ID can not be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC authorization.

Manual Information To the End User

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user's manual of the end product which integrates this module.
The end user manual shall include all required regulatory information/warning as show in this manual.

OEM/Host manufacturer responsibilities

OEM/Host manufacturers are ultimately responsible for the compliance of the Host and Module. The final product must be reassessed against all the essential requirements of the FCC rule such as FCC Part 15 Subpart B before it can be placed on the US market. This includes reassessing the transmitter module for compliance with the Radio and EMF essential requirements of the FCC rules. This module must not be incorporated into any other device or system without retesting for compliance as multi-radio and combined equipment.

Annex 3: Industry Canada statement

This device complies with ISED's licence-exempt RSSs. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Le présent appareil est conforme aux CNR d' ISED applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) le dispositif ne doit pas produire de brouillage préjudiciable, et (2) ce dispositif doit accepter tout brouillage reçu, y compris un brouillage susceptible de provoquer un fonctionnement indésirable.

Radiation Exposure Statement:

This equipment complies with ISED radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with greater than 20cm between the radiator & your body.

Déclaration d'exposition aux radiations:

Cet équipement est conforme aux limites d'exposition aux rayonnements ISED établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé à plus de 20 cm entre le radiateur et votre corps.

This device is intended only for OEM integrators under the following conditions: (For module device use)

1) The antenna must be installed and operated with greater than 20cm between the antenna and users, and
2) The transmitter module may not be co-located with any other transmitter or antenna.

As long as 2 conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

Cet appareil est conçu uniquement pour les intégrateurs OEM dans les conditions suivantes: (Pour utilisation de dispositif module)

1) L'antenne doit être installé et exploité avec plus de 20 cm entre l'antenne et les utilisateurs, et

2) Le module émetteur peut ne pas être coïmplanté avec un autre émetteur ou antenne.

Tant que les 2 conditions ci-dessus sont remplies, des essais supplémentaires sur l'émetteur ne seront pas nécessaires. Toutefois, l'intégrateur OEM est toujours responsable des essais sur son produit final pour toutes exigences de conformité supplémentaires requis pour ce module installé.

IMPORTANT NOTE:

In the event that these conditions cannot be met (for example certain laptop configurations or co-location with another transmitter), then the Canada authorization is no longer considered valid and the IC ID cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate Canada authorization.

NOTE IMPORTANTE:

Dans le cas où ces conditions ne peuvent être satisfaites (par exemple pour certaines configurations d'ordinateur portable ou de certaines co-localisation avec un autre émetteur), l'autorisation du Canada n'est plus considéré comme valide et l'ID IC ne peut pas être utilisé sur le produit final. Dans ces circonstances, l'intégrateur OEM sera chargé de réévaluer le produit final (y compris l'émetteur) et l'obtention d'une autorisation distincte au Canada.

End Product Labeling

This transmitter module is authorized only for use in device where the antenna may be installed and operated with greater than 20cm between the antenna and users. The final end product must be labeled in a visible area with the following: “Contains IC: 10506A-DF8”.

Plaque signalétique du produit final

Ce module émetteur est autorisé uniquement pour une utilisation dans un appareil où l’antenne peut être installée et utilisée à plus de 20 cm entre l’antenne et les utilisateurs. Le produit final doit être étiqueté dans un endroit visible avec l'inscription suivante: "Contient des IC: 10506A-DF8".

Manual Information To the End User

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user’s manual of the end product which integrates this module.
The end user manual shall include all required regulatory information/warning as show in this manual.

Manuel d'information à l'utilisateur final

L'intégrateur OEM doit être conscient de ne pas fournir des informations à l'utilisateur final quant à la façon d'installer ou de supprimer ce module RF dans le manuel de l'utilisateur du produit final qui intègre ce module. Le manuel de l'utilisateur final doit inclure toutes les informations réglementaires requises et avertissements comme indiqué dans ce manuel.

Annex 4: Doppler Equation

Where

$$F_d = 2V\left(\frac{F_t}{c}\right)\mathrm{Cos}\,\theta$$

F_d = Doppler frequency
V = Velocity of the target
F_t = Transmit frequency
c = Speed of light (3 X 10^8m/sec)
θ = The angle between the target moving direction and the axis of the module.

If a target is moving straight toward or away from DF100 (F_t = 24.125 GHz) The formula is simplified to:

F_d = 44.7V (Velocity in km/hour) or 71.9*V* (*V* in mile per hour)