**MICROCHIP**

# MRF24J40MB
# Data Sheet

## 2.4 GHz IEEE Std. 802.15.4™
## 20 dBm RF Transceiver Module

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# MRF24J40MB

## 2.4 GHz IEEE Std. 802.15.4™ 20 dBm RF Transceiver Module

### Features:

- IEEE Std. 802.15.4™ Compliant RF Transceiver
- Supports ZigBee®, MiWi™, MiWi P2P and Proprietary Wireless Networking Protocols
- Small Size: 0.9" x 1.3" (22.9 mm x 33.0 mm), Surface Mountable
- Integrated Crystal, Internal Voltage Regulator, Matching Circuitry, Power Amplifier, Low Noise Amplifier and PCB Antenna
- Easy Integration into Final Product – Minimize Product Development, Quicker Time to Market
- Radio Regulation Certification pending for United States (FCC), Canada (IC) and Europe (ETSI)
- Compatible with Microchip Microcontroller Families (PIC16F, PIC18F, PIC24F/H, dsPIC33 and PIC32)
- Up to 4000 ft. Range

### Operational:

- Operating Voltage: 2.4-3.6V (3.3V typical)
- Temperature Range: -40°C to +85°C Industrial
- Simple, Four-Wire SPI Interface
- Low-Current Consumption:
  - RX mode: 25 mA (typical)
  - TX mode: 130 mA (typical)
  - Sleep: 5 µA (typical)

### RF/Analog Features:

- ISM Band 2.405-2.48 GHz Operation
- Data Rate: 250 kbps
- -102 dBm Typical Sensitivity with -23 dBm Maximum Input Level
- +20 dBm Typical Output Power with 56 dB TX Power Control Range
- Integrated Low Phase Noise VCO, Frequency Synthesizer and PLL Loop Filter
- Digital VCO and Filter Calibration
- Integrated RSSI ADC and I/Q DACs
- Integrated LDO
- High Receiver and RSSI Dynamic Range

### MAC/Baseband Features:

- Hardware CSMA-CA Mechanism, Automatic ACK Response and FCS Check
- Independent Beacon, Transmit and GTS FIFO
- Supports all CCA modes and RSS/LQI
- Automatic Packet Retransmit Capable
- Hardware Security Engine (AES-128) with CTR, CCM and CBC-MAC modes
- Supports Encryption and Decryption for MAC Sublayer and Upper Layer

### FIGURE 1: PIN DIAGRAM



| | | | | |
|---|---|---|---|---|
| GND | 1 | | 12 | GND |
| RESET | 2 | | 11 | GND |
| WAKE | 3 | | 10 | V_IN |
| INT | 4 | | 9 | NC |
| SDI | 5 | | 8 | CS |
| SCK | 6 | | 7 | SDO |

**Advance Information**

# MRF24J40MB

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**Advance Information**

## 1.0 DEVICE OVERVIEW

The MRF24J40MB is a 2.4 GHz IEEE Std. 802.15.4™ compliant, surface mount module with integrated crystal, internal voltage regulator, matching circuitry, Power Amplifier, Low Noise Amplifier and PCB antenna. The MRF24J40MB module operates in the non-licensed 2.4 GHz frequency band. The integrated module design frees the integrator from extensive RF and antenna design, and regulatory compliance testing, allowing quicker time to market.

The MRF24J40MB module is compatible with Microchip's ZigBee®, MiWi™ and MiWi P2P software stacks. Each software stack is available as a free download, including source code, from the Microchip web site http://www.microchip.com/wireless.

The MRF24J40MB module is pending regulatory approvals for modular devices in the United States (FCC), Canada (IC) and Europe (ETSI). Modular approval removes the need for expensive RF and antenna design and allows the end user to place the MRF24J40MB module inside a finished product and not require regulatory testing for an intentional radiator (RF transmitter).

## 1.1 Interface Description

Figure 1-1 shows a simplified block diagram of the MRF24J40MB module. The module is based on the Microchip Technology MRF24J40 IEEE 802.15.4™ 2.4 GHz RF Transceiver IC. The module interfaces to many popular Microchip PIC® microcontrollers via a 4-wire serial SPI interface, interrupt, wake, Reset, power and ground, as shown in Figure 1-2. Table provides the pin descriptions.

Data communications with the MRF24J40MB module are documented in the *"MRF24J40 IEEE 802.15.4™ 2.4 GHz RF Transceiver Data Sheet"* (DS39776). Refer to the MRF24J40 Data Sheet for specific serial interface protocol and register definitions.

**FIGURE 1-1:** MRF24J40MB BLOCK DIAGRAM
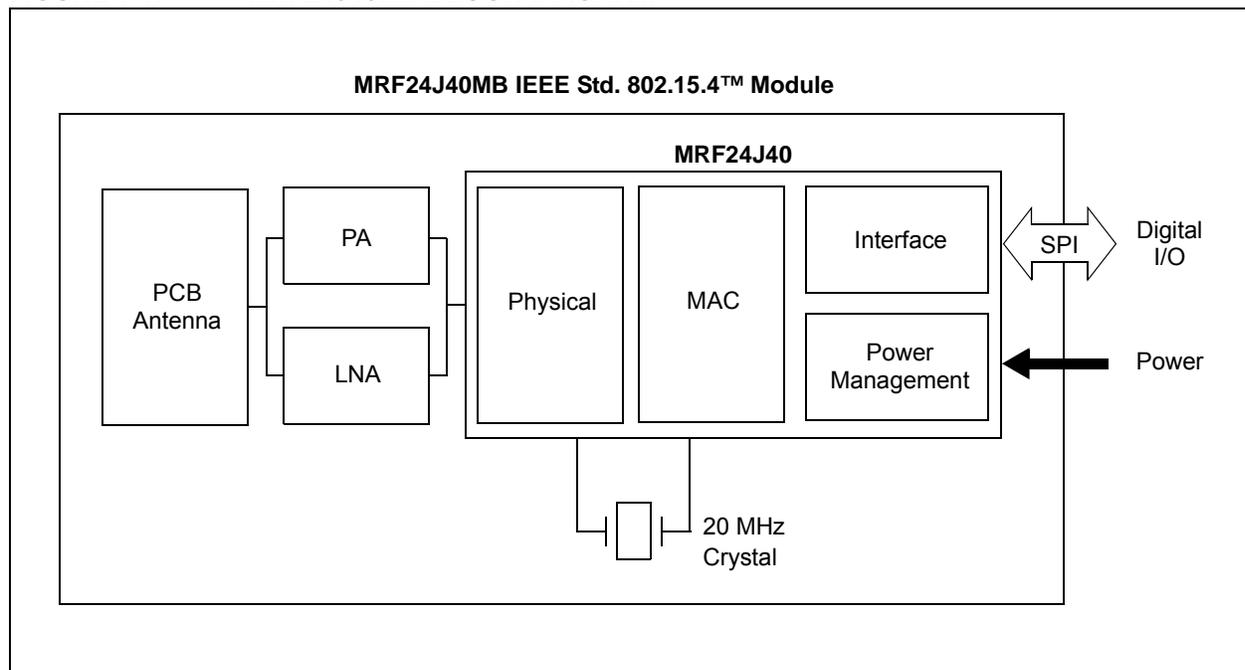


Note: This device has not been authorized as required by the rules of the Federal Communications Commission. This device is not, and may not be, offered for sale or lease, or sold or leased, until authorization is obtained.

# MRF24J40MB

**TABLE 1-1: PIN DESCRIPTION**

| Pin | Symbol | Type | Description |
|-----|--------|------|-------------|
| 1 | GND | Power | Ground |
| 2 | $\overline{\text{RESET}}$ | DI | Global hardware Reset pin |
| 3 | WAKE | DI | External wake-up trigger |
| 4 | INT | DO | Interrupt pin to microcontroller |
| 5 | SDI | DI | Serial interface data input |
| 6 | SCK | DI | Serial interface clock |
| 7 | SDO | DO | Serial interface data output from MRF24J40 |
| 8 | $\overline{\text{CS}}$ | DI | Serial interface enable |
| 9 | NC | — | No connection |
| 10 | $V_{IN}$ | Power | Power supply |
| 11 | GND | Ground | Ground |
| 12 | GND | Ground | Ground |

**Legend:** Pin type abbreviation: D = Digital, I = Input, O = Output

**FIGURE 1-2: MICROCONTROLLER TO MRF24J40MB INTERFACE**



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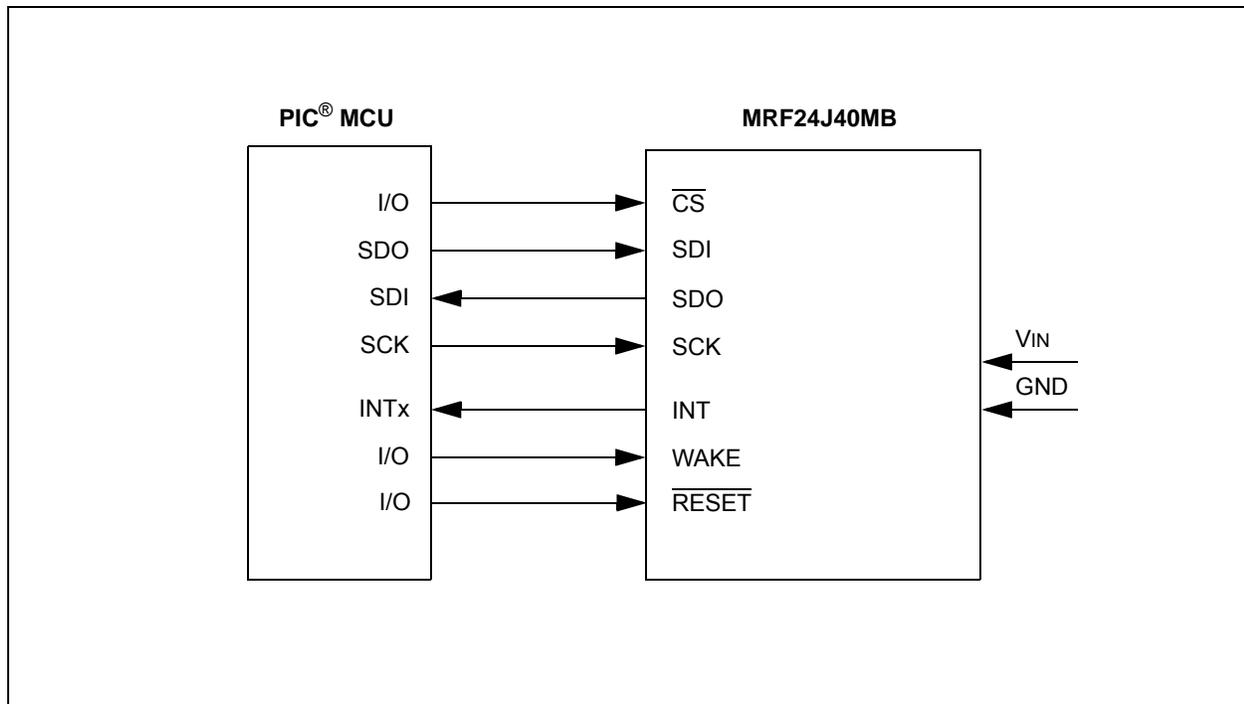
## 1.2 Mounting Details

The MRF24J40MB is a surface mountable module. Module dimensions are shown in Figure 1-3. The module Printed Circuit Board (PCB) is 0.032" thick with castellated mounting points on the edge. Figure 1-4 is a recommended host PCB footprint for the MRF24J40MB.

The MRF24J40MB has an integrated PCB antenna. For the best performance, follow the mounting details shown in Figure 1-5. It is recommended that the module be mounted on the edge of the host PCB, and an area around the antenna, approximately 1.2", be kept clear of metal objects. A host PCB ground plane around the MRF24J40MB acts as a counterpoise to the PCB antenna. It is recommended to extend the ground plane extend at least 0.4" around the module.

**FIGURE 1-3:**      **MODULE DETAILS**
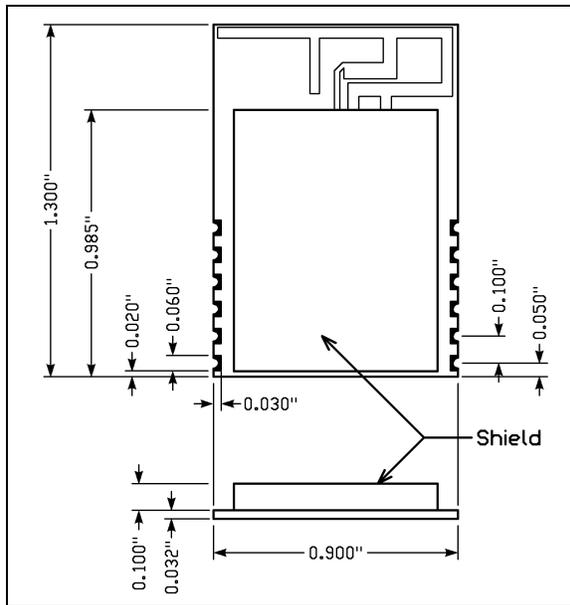


**FIGURE 1-4:**      **RECOMMENDED PCB FOOTPRINT**
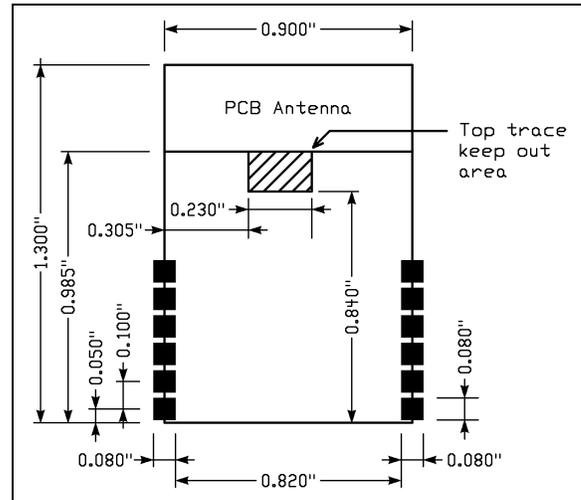
# MRF24J40MB

**FIGURE 1-5:** **MOUNTING DETAILS**



Keep area around antenna
(approximately 1.2 inches)
clear of metallic structures
for best performance

1.2"

Edge of PCB

0.315"

1.2"

0.4"

0.4"

0.4"

PCB Ground Plane (Counterpoise)
Underneath and extend as far as possible
to the sides and below the module
(at least 0.4 inches on each side)
for best performance

**Advance Information**
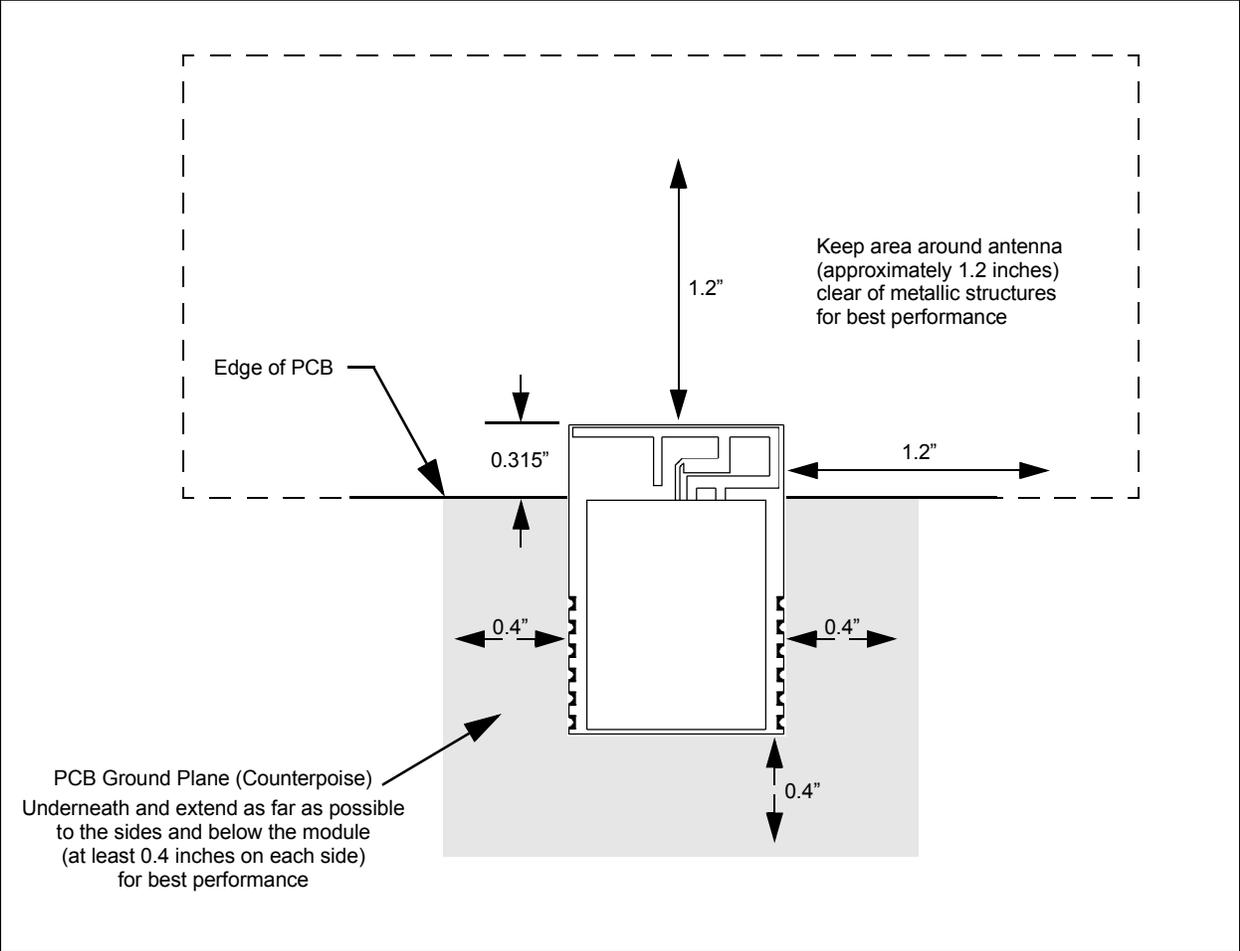
## 2.0 CIRCUIT DESCRIPTION

The MRF24J40MB is a complete 2.4 GHz IEEE Std. 802.15.4™ compliant surface mount module with integrated crystal, internal voltage regulator, matching circuitry, Power Amplifier, Low Noise Amplifier and PCB antenna. The MRF24J40MB module interfaces to many popular Microchip PIC microcontrollers via a 4-wire serial SPI interface, interrupt, wake, Reset, power and ground. Data communications with the MRF24J40MB module are documented in the "*MRF24J40 IEEE 802.15.4™ 2.4 GHz RF Transceiver Data Sheet*" (DS39776). Refer to the MRF24J40 Data Sheet for specific serial interface protocol and register definitions.

## 2.1 Schematic

A schematic diagram of the module is shown in Figure 2-1 and the Bill of Materials (BOM) is shown in Table 2-1.

The MRF24J40MB module is based on the Microchip Technology MRF24J40 IEEE 802.15.4™ 2.4 GHz RF Transceiver IC (U1). The serial I/O (SCK, SDI, SDO and $\overline{CS}$), $\overline{RESET}$, WAKE and INT pins are brought out to the module pins. The SDO signal is tri-state buffered by IC7 to solve a silicon errata, where the SDO signal does not release to a high-impedance state, after the $\overline{CS}$ pin returns to its inactive state.

Crystal, X1, is a 20 MHz crystal with a frequency tolerance of ±10 ppm @ 25°C to meet the IEEE Std. 802.15.4 symbol rate tolerance of ±40 ppm.

A balun is formed by components: L1, L3, C2 and C3. L2 is an RF choke and pull-up for the RFP and RFN pins on the MRF24J40. C4 is a DC block capacitor. RF switches IC2 and IC4 switch between the power amplifier IC3 when transmitting and low noise amplifier IC5 when receiving. A low-pass filter is formed by components: L10, L11, C31, C32 and C36. The remaining passive components provide bias and decoupling.

# MRF24J40MB

**FIGURE 2-1:** MRF24J40MB SCHEMATIC
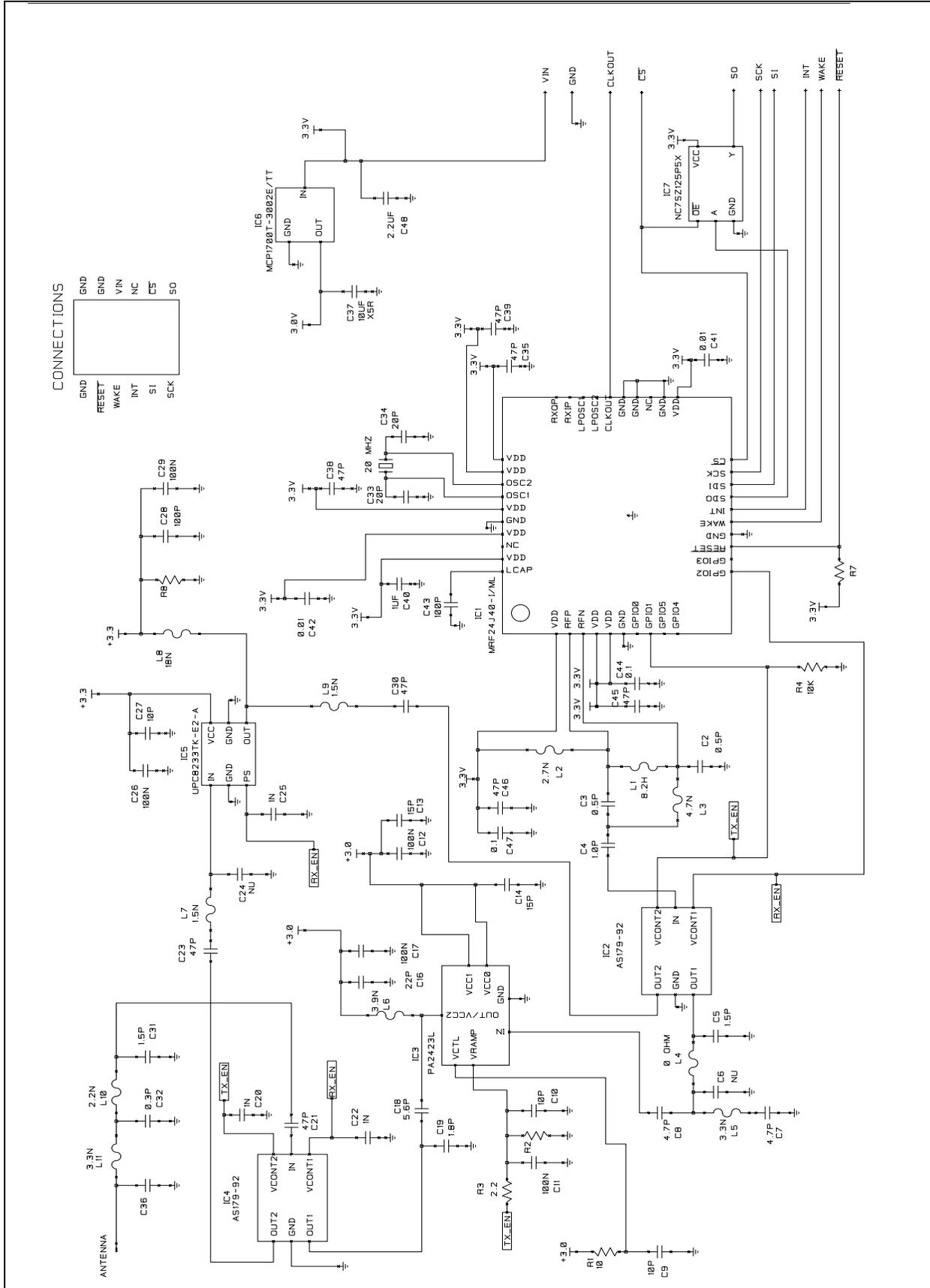
**TABLE 2-1:    MRF24J40MB BILL OF MATERIALS**

| Designator | Description | Manufacturer | Part Number |
|:---:|:---|:---|:---|
| C2 | Chip Capacitor 0402 COG 0.5P | Johanson Technology | 500R07S0R5AV4T |
| C3 | Chip Capacitor 0402 COG 0.5P | Johanson Technology | 500R07S0R5AV4T |
| C4 | Chip Capacitor 0402 COG 1.0P | Johanson Technology | 500R07S1R0BV4T |
| C5 | Chip Capacitor 0402 COG 1.5P | Murata | GRM1555C1H1R5CZ01D |
| C6 | Not Used | | |
| C7 | Chip Capacitor 0402 COG 4.7P | Murata | GRM1555C1H4R7CZ01D |
| C8 | Chip Capacitor 0402 COG 4.7P | Murata | GRM1555C1H4R7CZ01D |
| C9 | Chip Capacitor 0402 COG 10P | Murata | GRM1555C1H100JZ01D |
| C10 | Chip Capacitor 0402 COG 10P | Murata | GRM1555C1H100JZ01D |
| C11 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |
| C12 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |
| C13 | Chip Capacitor 0402 COG 15P | Murata | GRM1555C1H150JZ01D |
| C14 | Chip Capacitor 0402 COG 15P | Murata | GRM1555C1H150JZ01D |
| C16 | Chip Capacitor 0402 COG 22P | Murata | GRM1555C1H220JZ01D |
| C17 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |
| C18 | Chip Capacitor 0402 COG 5.6P | Murata | GRM1555C1H5R6CZ01D |
| C19 | Chip Capacitor 0402 COG 1.8P | Murata | GRM1555C1H1R8CZ01D |
| C20 | Chip Capacitor 0402 X7R 1N | Murata | GRM155R71H102KA01D |
| C21 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C22 | Chip Capacitor 0402 X7R 1N | Murata | GRM155R71H102KA01D |
| C23 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C24 | Not Used | | |
| C25 | Chip Capacitor 0402 X7R 1N | Murata | GRM155R71H102KA01D |
| C26 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |
| C27 | Chip Capacitor 0402 COG 10P | Murata | GRM1555C1H100JZ01D |
| C28 | Chip Capacitor 0402 COG 100P | Murata | GRM1555C1H101JZ01D |
| C29 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |
| C30 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C31 | Chip Capacitor 0402 COG 1.5P | Johanson Technology | 500R07S1R5BV4T |
| C32 | Chip Capacitor 0402 COG 0.4P | Johanson Technology | 500R07S0R4AV4T |
| C33 | Chip Capacitor 0402 COG 18P | Murata | GRM1555C1H180JZ01D |
| C34 | Chip Capacitor 0402 COG 18P | Murata | GRM1555C1H180JZ01D |
| C35 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C36 | Not Used | | |
| C37 | Chip Capacitor 0805 X5R 10U | Murata | GRM21BR60J106ME19L |
| C38 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C39 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C40 | Chip Capacitor 0402 X5R 1U | Murata | GRM155R60J105ME19D |
| C41 | Chip Capacitor 0402 X7R 10N | Murata | GRM155R71E103KA01D |
| C42 | Chip Capacitor 0402 X7R 10N | Murata | GRM155R71E103KA01D |
| C43 | Chip Capacitor 0402 COG 100P | Murata | GRM1555C1H101JZ01D |
| C44 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |
| C45 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C46 | Chip Capacitor 0402 X5R 100N | Murata | GRM155R61A104KA01D |

# MRF24J40MB

| Designator | Description | Manufacturer | Part Number |
|---|---|---|---|
| C47 | Chip Capacitor 0402 COG 47P | Murata | GRM1555C1H470JZ01D |
| C48 | Chip Capacitor 0603 X5R 2.2U | Murata | GRM188R60J225ME01D |
| IC1 | 802.15.4 Radio | Microchip | MRF24J40-I/ML |
| IC2 | Switch SPDT | Skyworks | AS179-92 |
| IC3 | Power Amplifier | SiGe | PA2423L-R |
| IC4 | Switch SPDT | Skyworks | AS179-92 |
| IC5 | Low Noise Amplifier | NEC | UPC8233TK-E2-A |
| IC6 | Voltage Regulator | Microchip | MCP1700T-3302E/TT |
| IC7 | Buffer-SC70 Package | Fairchild | NC7SZ125P5X |
| L1 | Chip Inductor 0402 8.2N | Panasonic | ELJ-RF8N2JFB |
| L2 | Chip Inductor 0402 2.7N | Panasonic | ELJ-RF2N7DFB |
| L3 | Chip Inductor 0402 4.7N | Panasonic | ELJ-RF4N7DFB |
| L4 | Chip Resistor 0402 0Ohms | Dale | CRCW04020000Z0ED |
| L5 | Chip Inductor 0402 3.3N | Panasonic | ELJ-RF3N3DFB |
| L6 | Chip Inductor 0402 3.9N | Panasonic | ELJ-RF3N9DFB |
| L7 | Chip Inductor 0402 1.5N | Panasonic | ELJ-RF1N5DFB |
| L8 | Chip Inductor 0402 18N | Panasonic | ELJ-RF18NJFB |
| L9 | Chip Inductor 0402 1.5N | Panasonic | ELJ-RF1N5DFB |
| L10 | Chip Inductor 0402 2.2N | Panasonic | ELJ-RF2N2DFB |
| L11 | Chip Inductor 0402 2.7N | Panasonic | ELJ-RF2N7DFB |
| R1 | Chip Resistor 0402 10Ohms 5% | Dale | CRCW040210R0JNED |
| R2 | Not Used | | |
| R3 | Chip Resistor 0402 2.2Ohms 5% | Dale | CRCW04022R20JNED |
| R4 | Chip Resistor 0402 10K 5% | Dale | CRCW040210K0JNED |
| R7 | Not Used | | |
| R8 | Not Used | | |
| S | Shield-Custom | TBD | |
| X1 | 20 MHz Crystal | Abracon | ABM8-156-20.0000MHZ-T |

**Note:**    Capacitors and inductors cannot be substituted.

## 2.2 Printed Circuit Board

The MRF24J40MB module printed circuit board is constructed with FR4 material, four layers and 0.032 inches thick. The layers are shown in Figure 2-2 through Figure 2-6. The stack up of the PCB is shown in Figure 2-7.

**FIGURE 2-2:** **TOP SILK SCREEN**
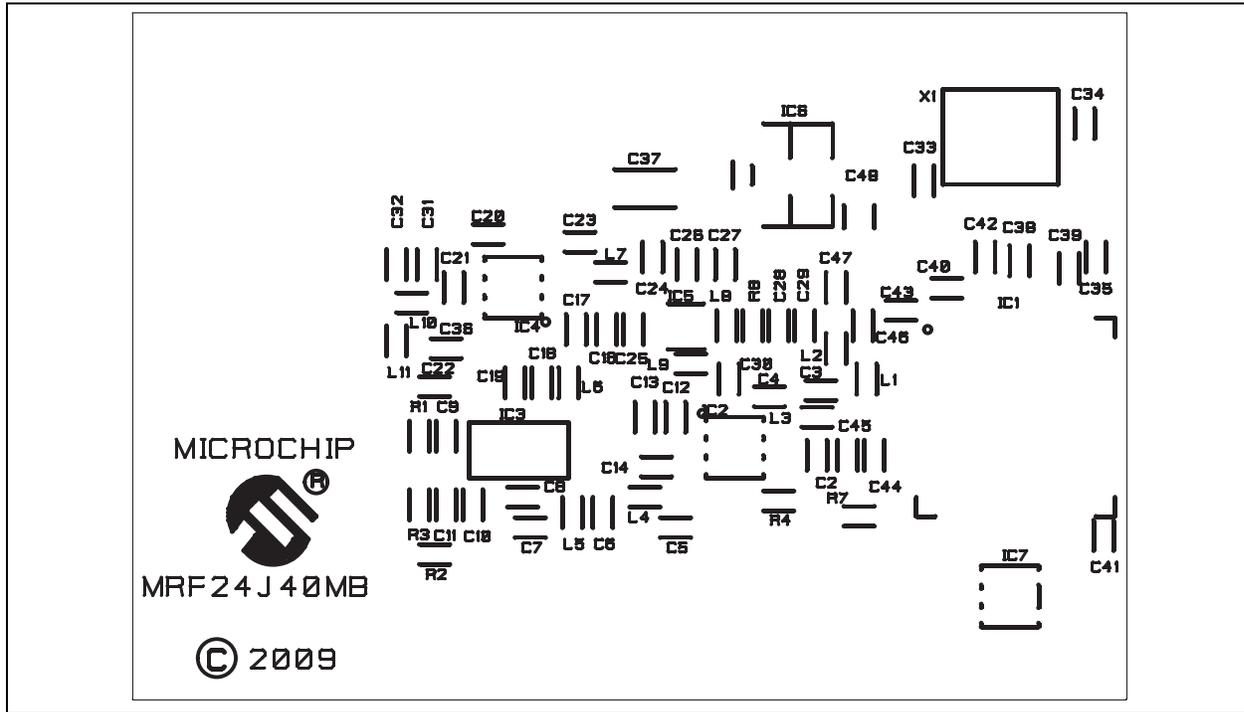


**FIGURE 2-3:** **TOP COPPER**
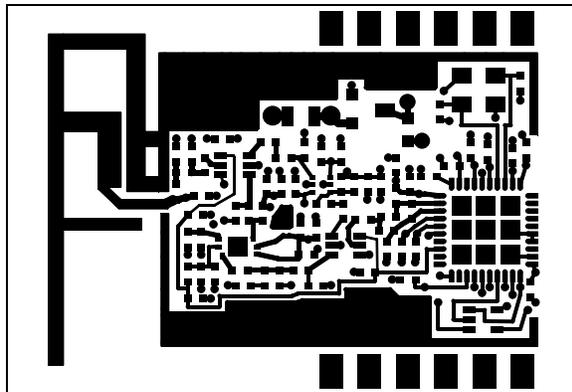


**FIGURE 2-4:** **LAYER 2 – GROUND PLANE**



**Note:** Top view negative Gerber.
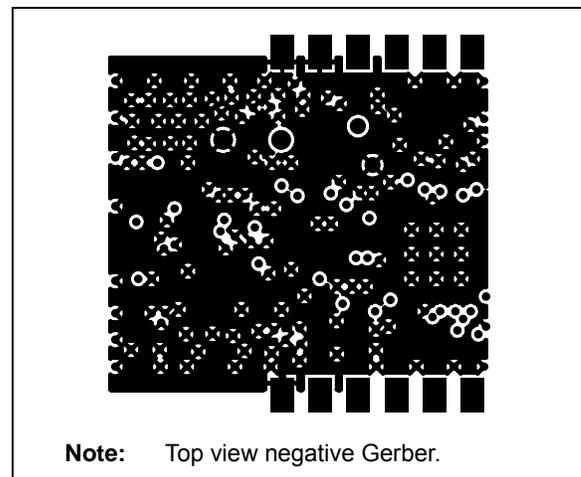
# MRF24J40MB

**FIGURE 2-5:** **LAYER 3 – POWER PLANE**



**Note:** Top view negative Gerber.
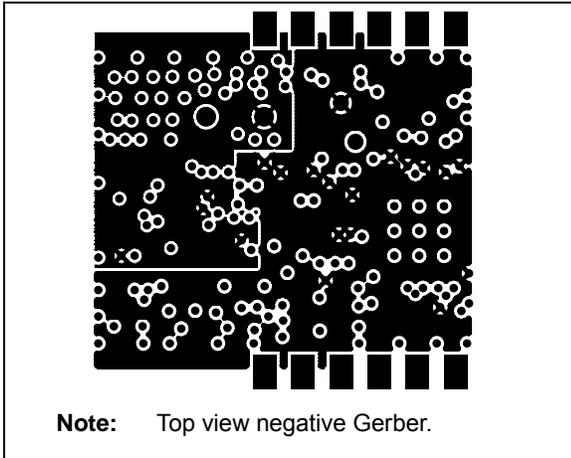
**FIGURE 2-6:** **BOTTOM COPPER**



**Note:** Top view.
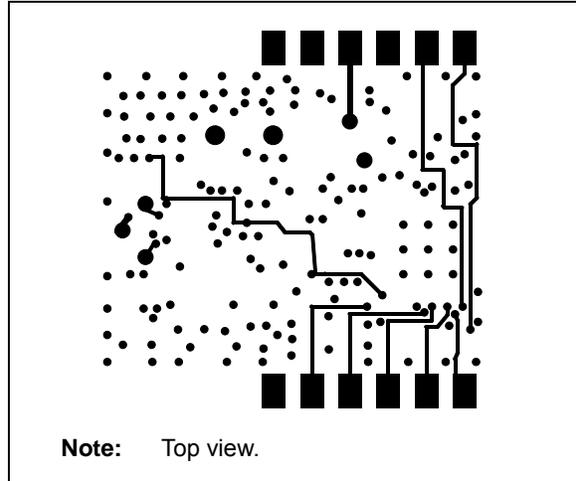
**FIGURE 2-7:** **PCB LAYER STACK UP**



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# MRF24J40MB

## 2.3    PCB Antenna

The PCB antenna is fabricated on the top copper trace. Figure 2-8 shows the trace dimensions. The layers below the antenna have no copper traces. The ground and power planes under the components serve as a counterpoise to the PCB antenna. Additional ground plane on the host PCB will substantially enhance the performance of the module. For best performance, place the module on the host PCB following the recommendations in **Section 1.2 "Mounting Details"**.

The Printed Circuit Board (PCB) antenna was designed and simulated using Ansoft Designer® and HFSS™ 3D full-wave solver software by Ansoft Corporation

(www.ansoft.com). The design goal was to create a compact, low-cost antenna with the best radiation pattern. Figure 2-9 shows the simulation drawing and Figure 2-10 and Figure 2-11 show the 2D and 3D radiation patterns, respectively. As shown by the radiation patterns, the performance of the antenna is dependant upon the orientation of the module. Figure 2-12 shows the impedance simulation and Figure 2-13 shows the SWR simulation. The discrete matching circuitry matches the impedance of the antenna with the MRF24J40 transceiver IC.

**FIGURE 2-8:        PCB ANTENNA DIMENSIONS**



**Note  1:**    Dimensions are in mm and tolerance is +/– 0.05 mm.

# MRF24J40MB

**FIGURE 2-9:** **PCB ANTENNA SIMULATION DRAWING**
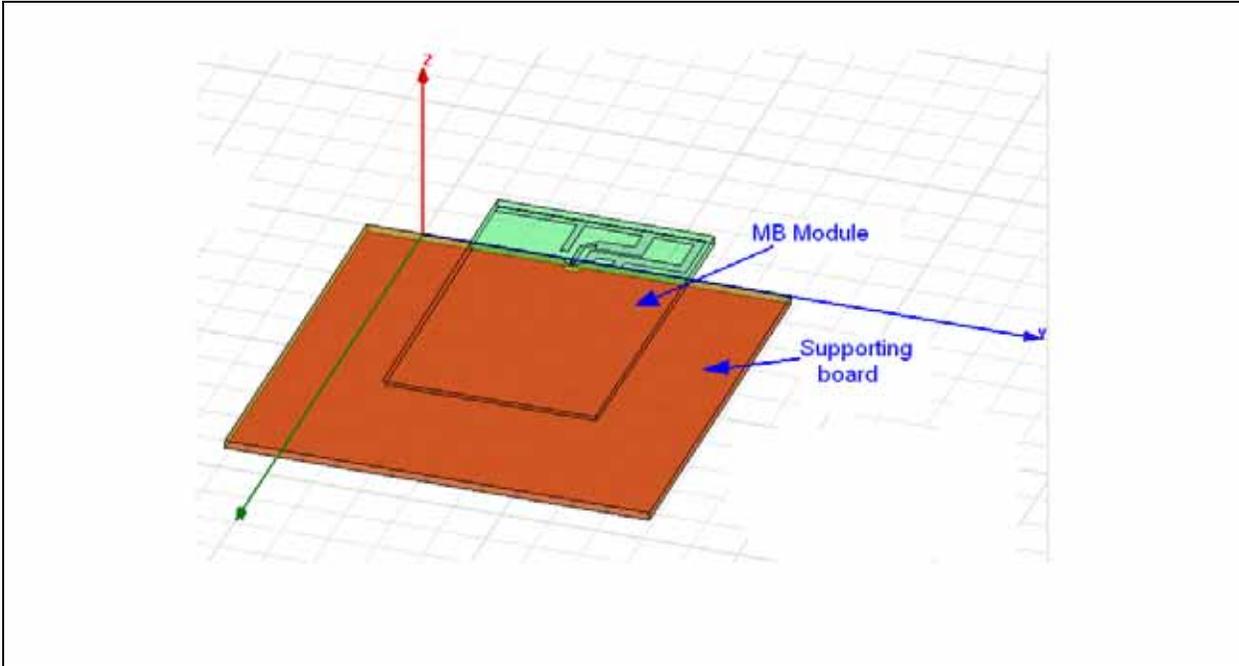


**FIGURE 2-10:** **SIMULATED 2D RADIATION PATTERN**



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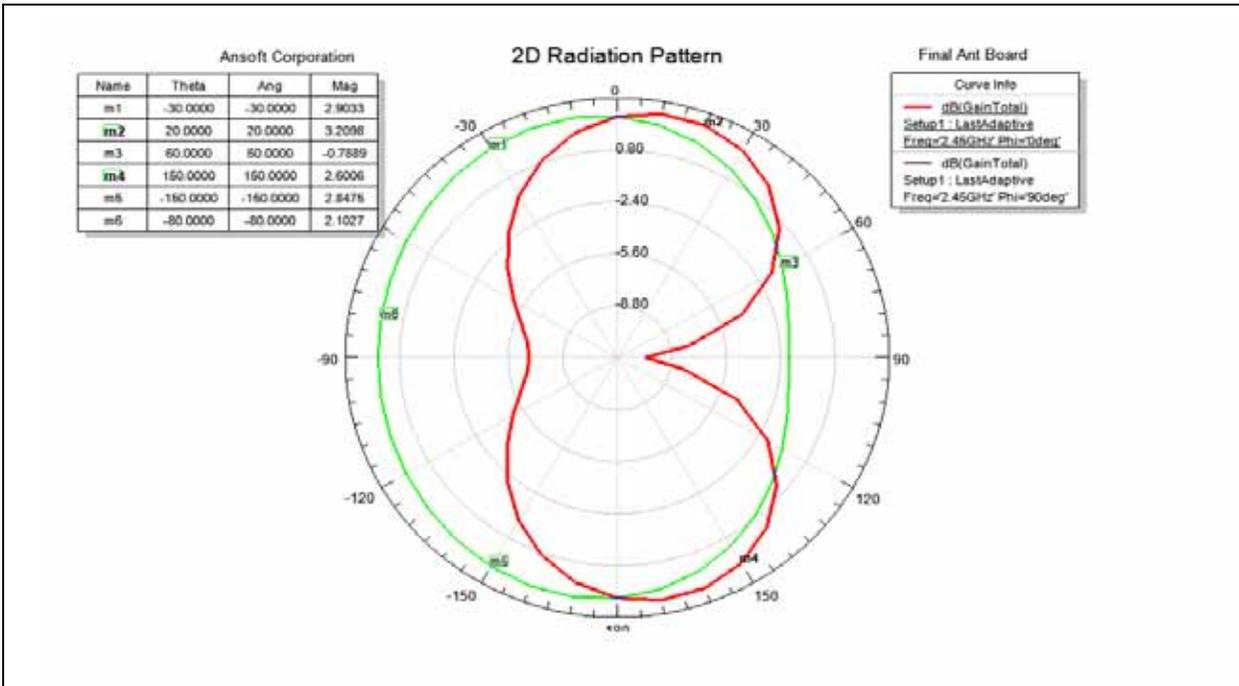
**FIGURE 2-11:** **SIMULATED 3D RADIATION PATTERN**
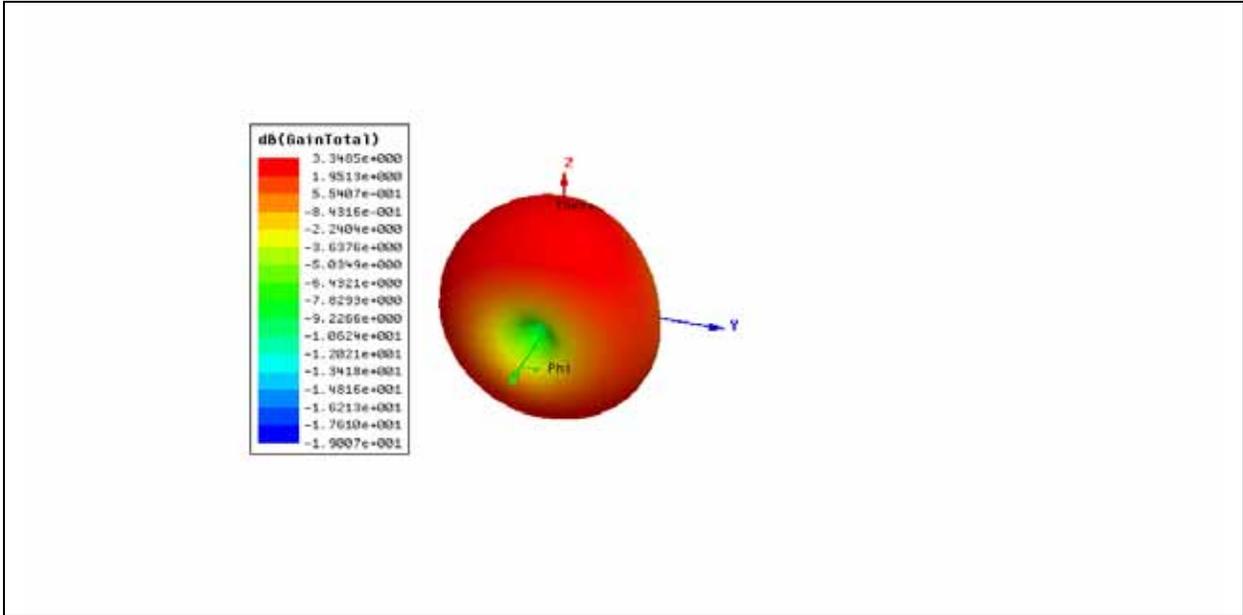


**FIGURE 2-12:** **SIMULATED PCB ANTENNA IMPEDANCE**
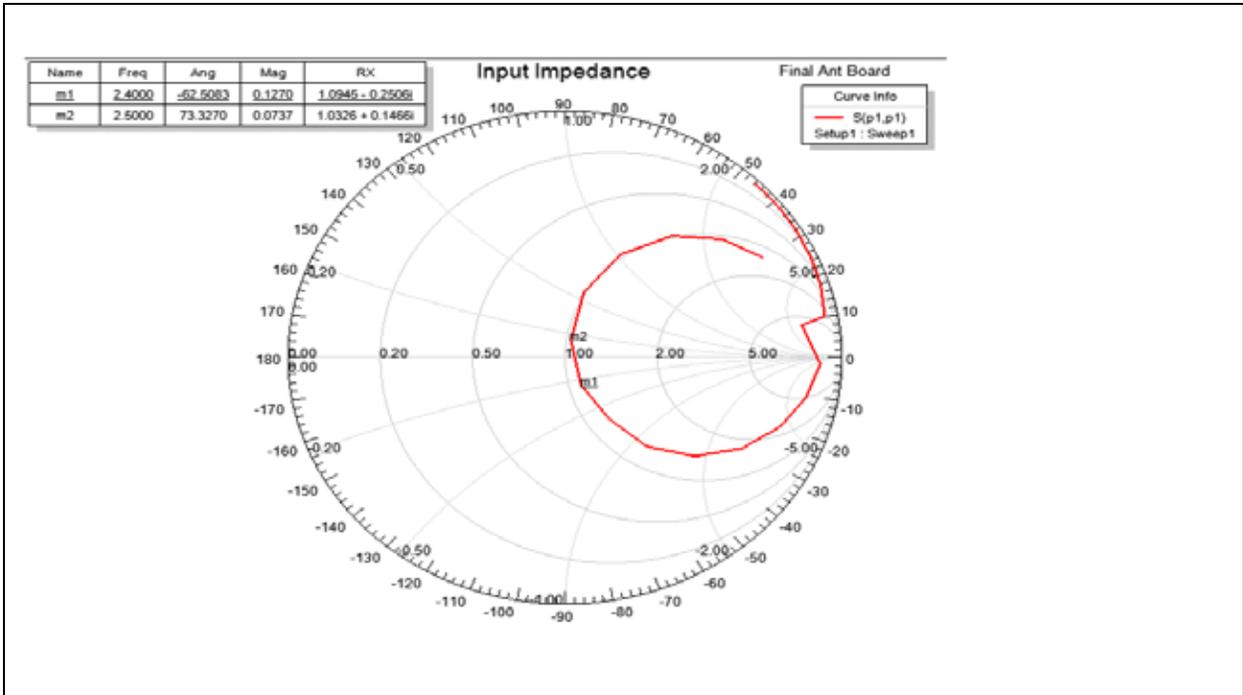
**FIGURE 2-13:** **SIMULATED PCB ANTENNA SWR**

# MRF24J40MB
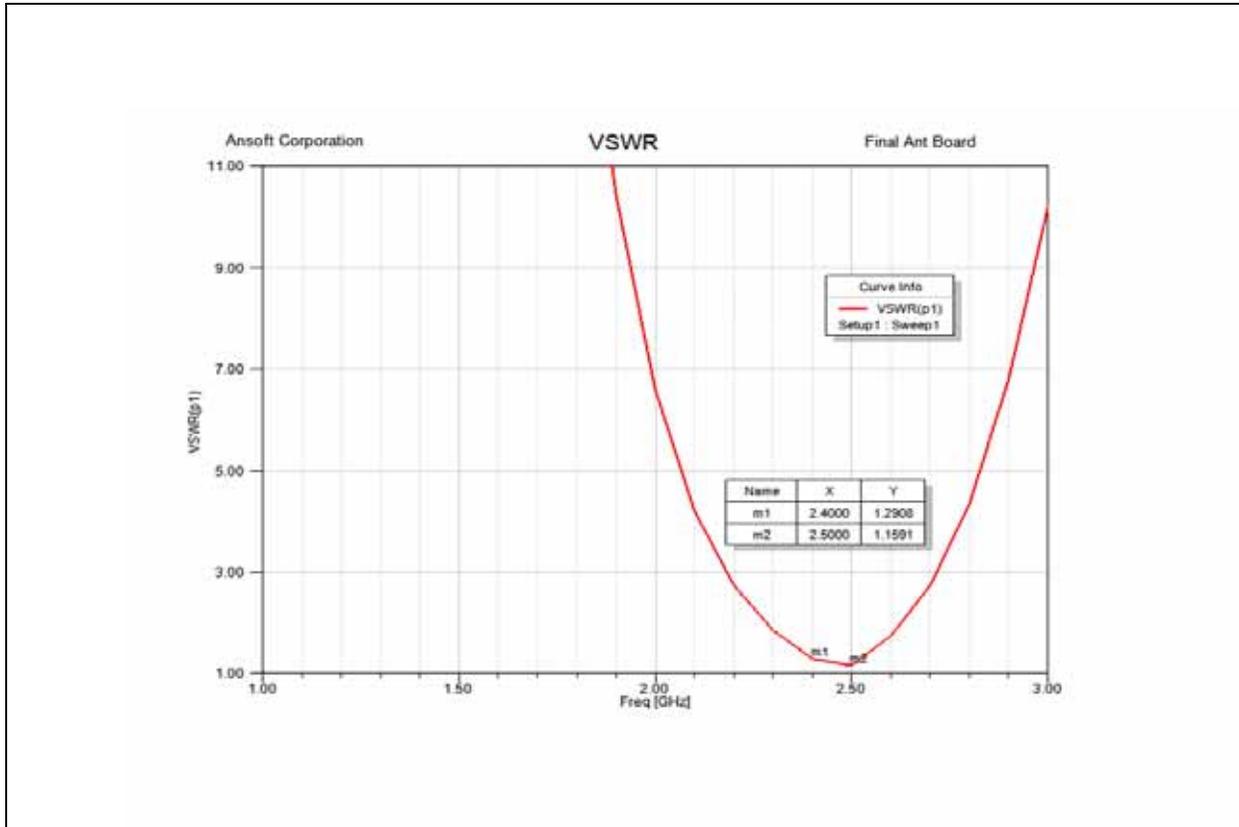
## 3.0    ELECTRICAL CHARACTERISTICS

### TABLE 3-1:    RECOMMENDED OPERATING CONDITIONS

| Parameters | Min | Typ | Max | Units |
|---|---|---|---|---|
| Ambient Operating Temperature | -40 | — | +85 | °C |
| Supply Voltage for RF, Analog and Digital Circuits | 2.4 | — | 3.6 | V |
| Supply Voltage for Digital I/O | 2.4 | 3.3 | 3.6 | V |
| Input High Voltage (V$_{IH}$) | 0.5 x V$_{DD}$ | — | V$_{DD}$ + 0.3 | V |
| Input Low Voltage (V$_{IL}$) | -0.3 | — | 0.2 x V$_{DD}$ | V |

### TABLE 3-2:    CURRENT CONSUMPTION

(T$_A$ = 25°C, V$_{DD}$ = 3.3V)

| Chip Mode | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Sleep | Sleep Clock Disabled | — | 5µA | — | µA |
| TX | At Maximum Output Power | — | 130mA | — | mA |
| RX | | — | 25mA | — | mA |

### TABLE 3-3:    RECEIVER AC CHARACTERISTICS

Typical values are at T$_A$ = 25°C, V$_{DD}$ = 3.3V, LO Frequency = 2.445 GHz

| Parameters | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| RF Input Frequency | Compatible to IEEE Std. 802.15.4™, 2003 | 2.405 | — | 2.480 | GHz |
| RF Sensitivity | | — | -102 | — | dBm |
| Maximum RF Input | | -23 | — | — | dBm |
| LO Leakage | Measured at Balun Matching Network Input at Frequency, 2.405-2.48 GHz | — | -60 | — | dBm |
| Input Return Loss | | -8 | -12 | — | dB |
| Noise Figure (including matching) | | — | 1.9 | — | dB |
| Adjacent Channel Rejection | @ +/-5 MHz | 30 | — | — | dB |
| Alternate Channel Rejection | @ +/-10 MHz | 40 | — | — | dB |
| RSSI Range | | — | 50 | — | dB |
| RSSI Error | | -5 | — | 5 | dB |

## TABLE 3-4: TRANSMITTER AC CHARACTERISTICS

Typical values are at $T_A$ = 25°C, $V_{DD}$ = 3.3V, LO Frequency = 2.445 GHz

| Parameters | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| RF Carrier Frequency | | 2.405 | — | 2.480 | GHz |
| Maximum RF Output Power | | — | 20 | — | dBm |
| RF Output Power Control Range | | — | 56 | — | dB |
| TX Gain Control Resolution | Programmed by Register | — | 1.25 | — | dB |
| Carrier Suppression | | — | -30 | — | dBc |
| TX Spectrum Mask for O-QPSK Signal | Offset Frequency > 3.5 MHz, at 0 dBm Output Power | -33 | — | — | dBm |
| TX EVM | | — | 15 | — | % |

## APPENDIX A: REVISION HISTORY

### Revision A (June 2009)

Original release of this document.

**NOTES:**

## INDEX

# MRF24J40MB

**NOTES:**

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|----------|---|---|---|-----|
| Device | Module | Module Type | Tape and Reel | Temperature Range |

Device          MRF24J40MB;
                VDD range 2.4V to 3.6V

Temperature Range    I        =  -40°C to   +85°C    (Industrial)

**Examples:**

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