



The Infinite Bandwidth Company™

MICRF102

QwikRadio™ UHF ASK Transmitter

Preliminary Information

General Description

The MICRF102 is a single chip Transmitter IC for remote wireless applications. The device employs Micrel's latest QwikRadio™ technology. This device is a true "data-in, antenna-out" monolithic device. All antenna tuning is accomplished automatically within the IC which eliminates manual tuning, and reduces production costs. The result is a highly reliable yet extremely low cost solution for high volume wireless applications. Because the MICRF102 is a true single-chip radio transmitter, it is easy to apply, minimizing design and production costs, and improving time to market.

The MICRF102 uses a novel architecture where the external loop antenna is tuned to the internal UHF synthesizer. This transmitter is designed to comply worldwide UHF unlicensed band intentional radiator regulations. The IC is compatible with virtually all ASK/OOK (Amplitude Shift Keying/On-Off Keyed) UHF receiver types from wide-band super-regenerative radios to narrow-band, high performance super-heterodyne receivers. The transmitter is designed to work with transmitter data rates from 100 to 20k bits per second.

The automatic tuning in conjunction with the external resistor, insures that the transmitter output power stays constant for the life of the battery.

When coupled with Micrel's family of QwikRadio™ receivers, the MICRF102 provides the lowest cost and most reliable remote actuator and RF link system available.

Features

- Complete UHF transmitter on a monolithic chip
- Frequency range 300MHz to 470MHz
- Data rates to 20kbps
- Automatic antenna alignment, no manual adjustment
- Low external part count
- Low standby current <1μA

Applications

- Remote Keyless Entry Systems (RKE)
- Remote Fan/Light Control
- Garage Door Opener Transmitters
- Remote Sensor Data Links

Ordering Information

Part Number	Temperature Range	Package
MICRF102BM	-40°C to +85°C	8-Pin SOIC

Typical Application

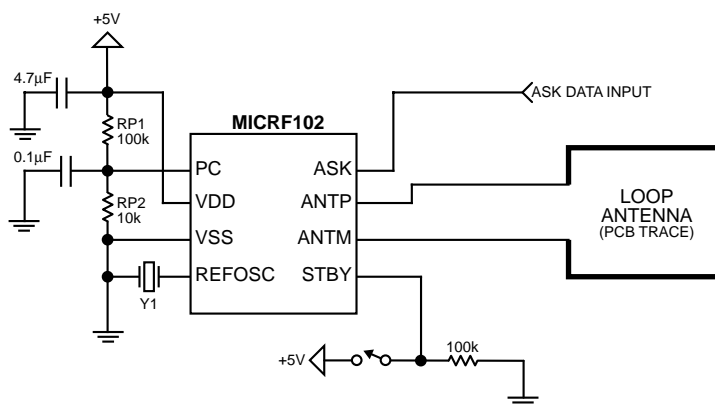
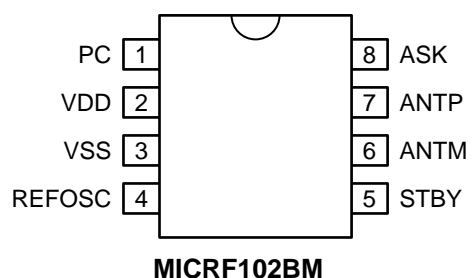


Figure 1

QwikRadio is a trademark of Micrel, Inc. The QwikRadio ICs were developed under a partnership agreement with AIT of Orlando, Florida

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Pin Configuration



Pin Description

Pin Number	Pin Name	Pin Function
1	PC	Power Control Input. The voltage at this pin should be set between 0.2V to 0.4V for normal operation.
2	VDD	Positive power supply input for the IC.
3	VSS	This pin is the ground return for the IC. A power supply bypass capacitor connected from VDD to VSS should have the shortest possible path.
4	REFOSC	This is the timing reference frequency which is the transmit frequency divided by 32. Connect a crystal (mode dependent) between this pin and VSS, or drive the input with an AC coupled 0.5Vpp input clock. See <i>Reference Oscillator</i> Section in this data sheet
5	STBY	Input for transmitter stand by control pin is pulled to VDD for transmit operation and VSS for stand-by mode.
6	ANTM	Negative RF power output to drive the low side of the transmit loop antenna
7	ANTP	Positive RF power output to drive the high side of the transmit loop antenna
8	ASK	Amplitude Shift Key modulation data input pin. For CW operation, connect this pin to VDD

Absolute Maximum Ratings (Note 1)

Supply Voltage (V_{DD})	+6V
Voltage on I/O Pins	$V_{SS}-0.3$ to $V_{DD}+0.3$
Storage Temperature Range	-65°C to +150°C
Lead Temperature (soldering, 10 seconds)	+300°C
ESD Rating	Note 3

Operating Ratings (Note 2)

Supply Voltage (V_{DD})	4.5V to 5.5V
Maximum Supply Ripple Voltage	10mV
PC Input Range	0V < V_{PC} < 0.6V
Ambient Operating Temperature (T_A)	-40°C to +85°C
Programmable Transmitter Frequency Range	300MHz to 470MHz

Electrical Characteristics

Specifications apply for 4.75V < V_{DD} < 5.5V, V_{PC} = 0.2V, T_A = 25°C, $\text{freq}_{\text{REFOSC}}$ = 12.1875MHz, STBY = V_{DD} . **Bold** values indicate -40°C ≤ T_A ≤ 85°C unless otherwise noted.

Parameter	Condition	Min	Typ	Max	Units
Power Supply					
Standby supply current, I_q	STBY = V_{SS}		1.0		μA
MARK supply current, I_{ON}	@315MHz, Note 4		7.5		mA
	@433MHz, Note 4		9.5		mA
SPACE supply current, I_{OFF}	@315MHz		4		mA
	@433MHz		6		mA
Mean operating current	50% mark/space ratio at 315MHz, Note 4		5.75		mA
	50% mark/space ratio at 433MHz, Note 4		7.75		mA

RF Output Section and Modulation Limits:

Output power level, P_{OUT}	@315MHz (EIRP), Note 4		-2		dBm
	@433MHz (EIRP), Note 4		-2.5		dBm
Harmonics output, Note 10	@ 315MHz	2nd harm. 3rd harm.	-46 -45		dBc
	@433 MHz	2nd harm. 3rd harm.	-50 -41		dBc
Extinction ratio for ASK		40	52		dBc
Varactor tuning range	Note 5	5	6.5	8	pF

Reference Oscillator Section

Reference Oscillator Input Impedance			300		kΩ
Reference Oscillator Source Current			6		μA
Reference Oscillator Input Voltage (peak to peak)		0.2		0.5	V_{PP}

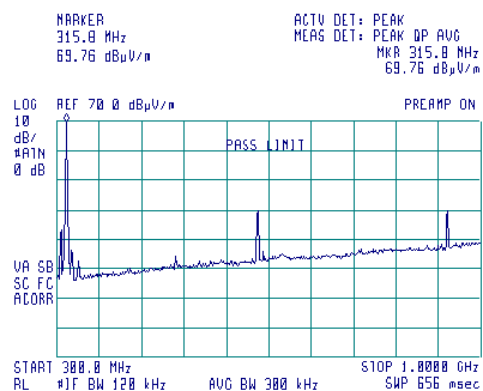
Digital / Control Section

Calibration time	Note 6, ASK=HIGH		25		ms
Power amplifier output hold off time from STBY	Note 7, STDBY transition from LOW to HIGH Crystal, ESR < 20Ω		6		ms
Transmitter Stabilization Time	From External Reference (500mVpp)		10		ms
	Crystal, ESR < 20Ω		19		ms
Maximum Data rate - ASK modulation	Duty cycle of the modulating signal = 50%	20			kbits/s
STBY HIGH	V_{STBY} LOW, R_{STBY} = 100kΩ to GND	0.8 V_{DD}			V
	I_{STBY} HIGH, R_{STBY} = 100kΩ to GND		60	80	μA
ASK pin	V_{IH} , input high voltage	0.8 V_{DD}			V
	V_{IL} , input low voltage			0.2 V_{DD}	V
ASK input current	ASK = 0V, 5.0V input current	-10	0.1	10	μA

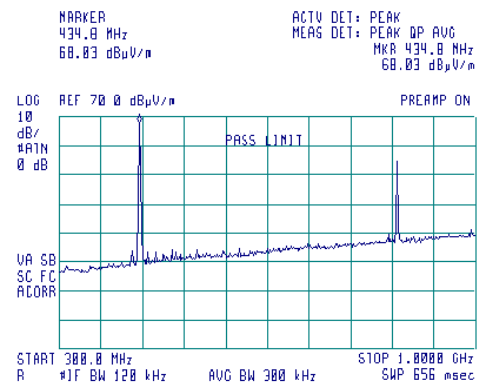
- Note 1.** Exceeding the absolute maximum rating may damage the device.
- Note 2.** The device is not guaranteed to function outside its operating rating.
- Note 3.** Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k in series with 100pF.
- Note 4.** Supply current and output power are a function of the voltage input on the PC (power control) pin. All specifications in the Electrical Characteristics table applies for condition $V_{PC} = 200\text{mA}$. Increasing the voltage on the PC pin will increase transmit power and also increase MARK supply current. Refer to the graphs "Output Power Versus PC Pin Voltage" and "Mark Current Versus PC Pin Voltage."
- Note 5.** The Varactor capacitance tuning range indicates the allowable external antenna component variation to maintain tune over normal production tolerances of external components. Guaranteed by design not tested in production.
- Note 6.** When the device is first powered up or it loses power momentarily, it goes into the calibration mode to tune up the transmit antenna.
- Note 7.** After the release of the STDBY, the device requires an initialization time to settle the REFOSC and the internal PLL. The first MARK state (ASK HIGH) after exit from STDBY needs to be longer than the initialization time. The subsequent low to high transitions will be treated as data modulation whereby the envelope transition time will apply.
- Note 8.** The MICRF102 was tested to be Compliant to Part 15.209 and 15.231 for maximum allowable TX power, when operated in accordance with a loop antenna described in Figure 6.

Typical Characteristics

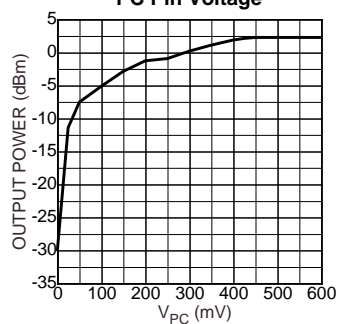
315MHz FCC 3 Meter Compliance Test



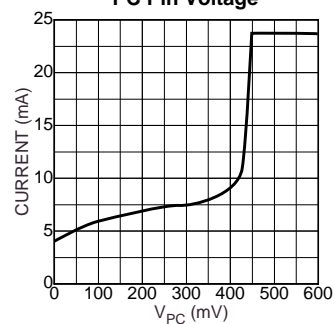
433MHz FCC 3 Meter Compliance Test



Output Power vs PC Pin Voltage



Mark Current vs PC Pin Voltage



Functional Diagram

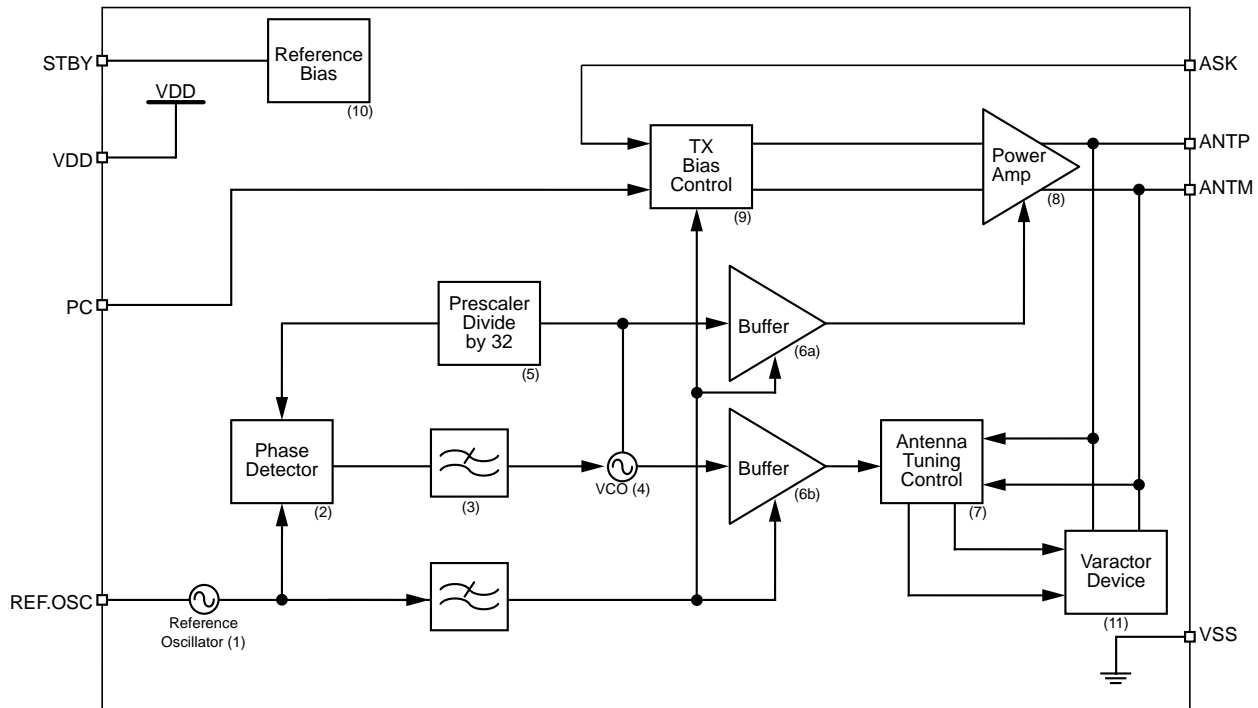


Figure 2. MICRF102 Block Diagram

Functional Description

The block diagram illustrates the basic structure of the MICRF102. Identified in the figure are the principal functional blocks of the IC, namely the (1, 2, 3, 4, 5) UHF Synthesizer, (6a/b) Buffer, (7) Antenna tuner, (8) Power amplifier, (9) TX bias control, (10) Reference bias and (11) Process tuner.

The UHF synthesizer generates the carrier frequency with quadrature outputs. The in-phase signal (I) is used to drive the PA and the quadrature signal (Q) is used to compare the antenna signal phase for antenna tuning purpose.

The Antenna tuner block senses the phase of the transmit signal at the antenna port and controls the varactor capacitor to tune the antenna.

The Power control unit senses the antenna signal and controls the PA bias current to regulate the antenna signal to the transmit power.

The Process tune circuit generates process independent bias currents for different blocks.

A PCB antenna loop coupled with a resonator and a resistor divider network are all the components required to construct a complete UHF transmitter for remote actuation applications such as automotive keyless entry.

Included within the IC is a differential varactor that serves as the tuning element to insure that the transmit frequency and antenna are aligned with the receiver over all supply and temperature variations.

Applications Information

Design Process

The MICRF102 transmitter design process is as follows:

- 1). Set the transmit frequency by providing the correct reference oscillator frequency
- 2). Ensure antenna resonance at the transmit frequency by:
 - a. Either, matching antenna inductance to the center of the tuning range of the internal varactor.
 - b. Or, matching capacitance with the antenna inductance by adding an external capacitor (in series with, or in parallel with, the internal varactor)
- 3). Set PC pin for desired transmit power.

Reference Oscillator Selection

An external reference oscillator is required to set the transmit frequency. The transmit frequency will be 32 times the reference oscillator frequency.

$$f_{TX} = 32 \times f_{REFOSC}$$

Crystals or a signal generator can be used. Correct reference oscillator selection is critical to ensure operation. Crystals must be selected with an ESR of 20 Ohms or less. If a signal generator is used, the input amplitude must be greater than 200 mV_{P-P} and less than 500 mV_{P-P}.

Antenna Considerations

The MICRF102 is designed specifically to drive a loop antenna. It has a differential output designed to drive an inductive load. The output stage of the MICRF102 includes a varactor that is automatically tuned to the inductance of the antenna to ensure resonance at the transmit frequency.

A high-Q loop antenna should be accurately designed to set the center frequency of the resonant circuit at the desired transmit frequency. Any deviation from the desired frequency will reduce the transmitted power. The loop itself is an inductive element. The inductance of a typical PCB-trace antenna is determined by the size of the loop, the width of the antenna traces, PCB thickness and location of the ground plane. The tolerance of the inductance is set by the manufacturing tolerances and will vary depending how the PCB is manufactured.

In the simplest implementation a single capacitor in parallel with the antenna will provide the desired resonant circuit.

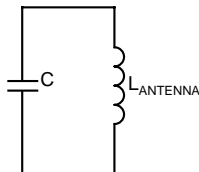


Figure 3.

The resonant frequency is determined by the equation:

$$f = \sqrt{\frac{1}{4\pi^2 CL}}$$

The tolerance in the antenna inductance combined with the tolerance of the capacitor in parallel with it will result in significant differences in resonant frequency from one transmitter to another. Many conventional loop antenna transmitters use a variable capacitor for manual tuning of the resonant circuit in production. Manual tuning increases cost and reduces reliability.

A capacitor correctly tuned during manufacture may drift over time and temperature. A change in capacitance will alter the resonant frequency and reduce radiated power. In addition, a hand close to the antenna will alter the resonant properties of the antenna and de-tune it.

The MICRF102 features automatic tuning. The MICRF102 automatically tunes itself to the antenna, eradicating the need for manual tuning in production. It also dynamically adapts to changes in impedance in operation and compensates for the hand-effect.

Automatic Antenna Tuning

The output stage of the MICRF102 consists of a variable capacitor (varactor) with a nominal value of 6.5pF tunable over a range from 5pF to 8pF. The MICRF102 monitors the phase of the signal on the output of the power amplifier and automatically tunes the resonant circuit by setting the varactor value at the correct capacitance to achieve resonance.

In the simplest implementation, the inductance of the loop antenna should be chosen such that the nominal value is resonant at 6.5pF, the nominal mid-range value of the MICRF102 output stage varactor.

Using the equation:

$$L = \frac{1}{4\pi^2 f^2 C}$$

If the inductance of the antenna cannot be set at the nominal value determined by the above equation, a capacitor can be added in parallel or series with the antenna. In this case, the varactor internal to the MICRF102 acts to trim the total capacitance value.

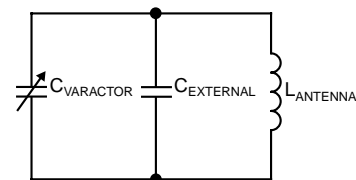


Figure 4.

Starting with the inductance of the antenna the capacitance value required to achieve resonance can be calculated.

For example a 315MHz transmitter with a 45.1nH inductance antenna will require no capacitor in parallel with the antenna, only the internal varactor that will be tuned to 5.66pF, which is very close to mid range and can be determined using the equation:

$$C = \frac{1}{4\pi^2 f^2 L}$$

Where:

$$f = 315\text{Mhz}$$

$$L = 45.1\text{nH}$$

The value of the capacitor is calculated as 5.66pF.

Supply Bypassing

Correct supply bypassing is essential. A 4.7uF capacitor in parallel with a 100pF capacitor is required and an additional 0.1uF capacitor in parallel is recommended.

The MICRF102 is susceptible to supply-line ripple, if supply regulation is poor or bypassing is inadequate, spurs will be evident in the transmit spectrum.

Transmit Power

The transmit power specified in this datasheet is normalized to a 50Ohm load. The antenna efficiency will determine the actual radiated power. Good antenna design will yield transmit power in the range of 67dBμV/m to 80dBμV/m at 3 meters.

The PC pin on the MICRF102 is used to set the transmit power. The differential voltage on the output of the PA (power amplifier) is proportional to the voltage at the PC pin.

If the PC pin voltage rises above 0.4 V the output power becomes current limited. At this point, further increase in the PC pin voltage will not increase the RF output power in the antenna pins. Low power consumption is achieved by decreasing the voltage in the PC pin, also reducing the RF output power and maximum range.

Output Blanking

When the device is first powered up or after a momentary loss of power the output is automatically blanked (disabled). This feature ensures RF transmission only occurs under controlled conditions when the synthesizer is fully operational, preventing unintentional transmission at an undesired frequency. Output blanking is key to guaranteeing compliance with UHF regulations by ensuring transmission only occurs in the intended frequency band.

Application Test Circuit

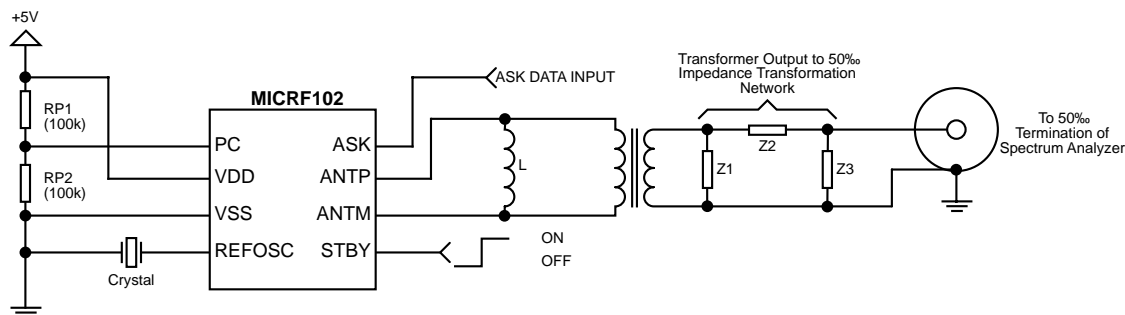


Figure 5. Application Test Circuit For Specification Verification

Design Examples

315MHz Reference Design

Full reference designs including gerber files can be downloaded from Micrel's website at www.micrel.com.

Antenna Characteristics

In this design, the desired loop inductance value is determined according to the table below. For 315 MHz the inductance is 45.1nH using the equation:

$$L = \frac{1}{4\pi^2 f^2 C}$$

Where:

$$f = 315\text{MHz}$$

$$C = 5.66\text{pF (tuning varactor)}$$

Freq. (MHz)	R (ohms)	XL (ohms)	Ind (nH)	Q (XL/R)
300	1.7	84.5	44.8	39.72
315	2.34	89.3	45.1	39.65
390	3.2	161	47.4	52.00
434	2.1	136	50.0	78.33

The reference design shown in Figure 6. has an antenna meeting this requirement.

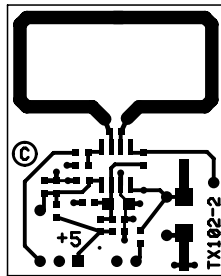


Figure 6

Loop antennas are often considered highly directional. In fact small loop antennas can achieve transmit patterns close in performance to a mono-pole antenna. The radiation pattern below is the theoretical radiation pattern for the antenna shown in Figure 6.

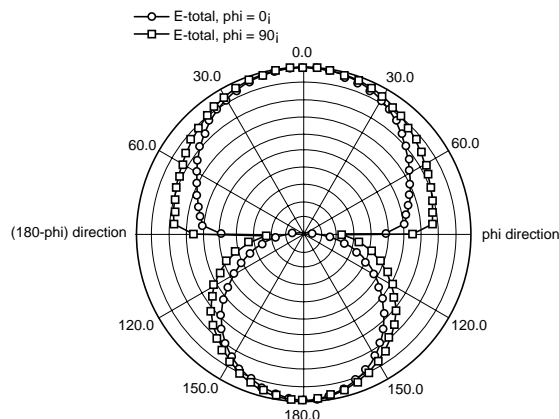


Figure 7. Polar Elevation pattern at 315MHz

The 0 degree plot is the radiation pattern in the plane of the transmitter PCB, the 90 degree plot represents the plane perpendicular to the PCB. Micrel's evaluation of the performance of the board in Figure 6. indicates an even more uniform radiation pattern than the theoretical plot shown here.

Supply Bypassing

Supply bypassing consists of three capacitors; C3 = 4.7uF, C4 = 0.1uF and C5 = 100pF

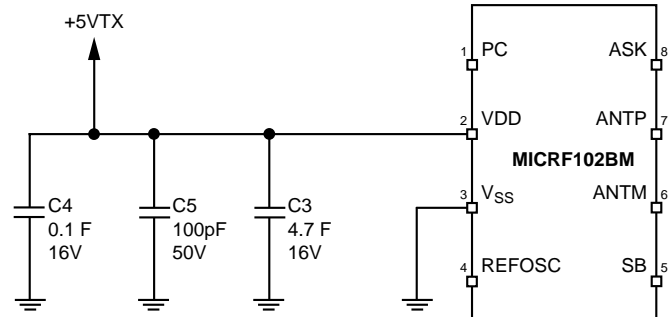


Figure 8.

433.92MHz Reference Design

The 433.92MHz reference design is essentially the same as the 315MHz design. The only change is a 2.2pF series capacitor to bring the varactor into tuning range. In this case the antenna inductance is 50nH.

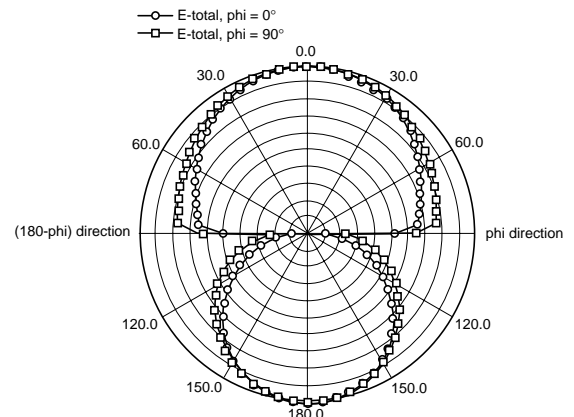
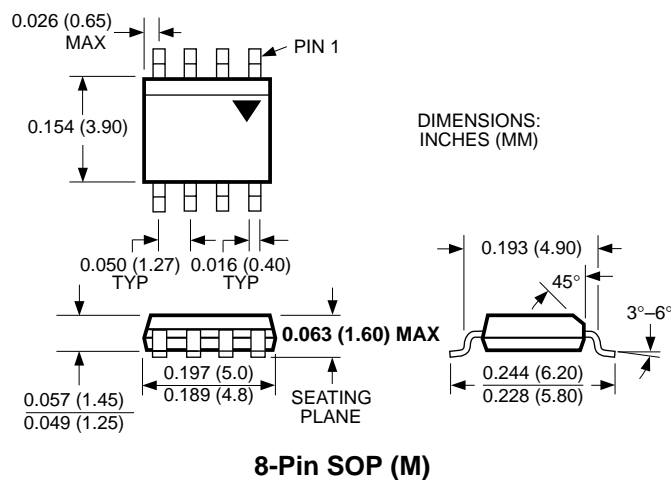


Figure 9. Polar Elevation pattern at 315MHz

Package Information



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