Application Note 55

How to go Through FCC Compliance Testing Using the MICRF112

Introduction

This application note will cover the use of Short Range Devices (SRD), which do not require a license for the MICRF112. These devices are mainly known as devices to be used in the ISM (Industrial, Scientific and Medical) band, requiring regulatory approval and acquiring an identification number. The TX112 will be used as an example of an intentional radiator for meeting compliance. A procedure will be shown on how to do preliminary tests to prepare for FCC compliance. The use of such a device is governed by laws and regulations that are different from country to country. This document will focus on Federal Communications Commission (FCC) and ETSI EN 300-220 regulations for USA and Europe, respectively, and will concentrate on FCC compliance testing. The following is the basic subject matter to be covered in the application note:

- Who Needs to Perform RF Compliant Testing?
- What is Regulatory Compliant Testing?
- Regulatory Agency and Compliant House.
- World Wide Regulatory Agencies.
- Brief Description of FCC CFR47 Part 15 and ETSI 300-220.
- Critical Tests.
- In-House Preliminary Testing.
- Pre-Compliance and Full Compliance Testing.
- Compliance Testing at the System Level.
- Power Calculations Using Isotropic Antennas.
- Three Meter FCC Results from a Compliance House.
- ETSI Pre-Testing.
- FAQ.

Who Needs to Perform RF Compliant Testing?

Anyone wishing to produce a RF product to be used by the general public must comply with regulatory standards. The objective is to share the airways and produce a safe and non-interfering device.

What is Regulatory Compliant Testing?

Any product that is considered an intentional or non-intentional short-range radiator that will share the air-ways must go through compliant testing. The regulatory requirements will give guidelines so other devices can work together in an efficient manner. In the USA, the FCC is responsible for regulating all RF devices. The Code of Federal Regulations 47, (CFR 47), Section 15.231 will be used to describe what requirements are needed for the TX112-1 or any similar product. to meet standards in the USA. Section 15, paragraph 231 describes requirements needed to place a RF product in many different configurations. Other sections of Part 15 may have to be used to qualify your product in US market. It is advised to consult with an experienced compliance house to recommend what section is applicable for your product corresponding to the desired market place.

Regulatory Agency and Compliant House

For FCC compliance, a request for an Identification Number, (ID) can be done after a product is necessarily tested by a certified compliance house. The request for an ID number will be submitted to a regulatory agency such as the FCC. Testing of the product can be done by a certified compliant house. Such a compliant house will have a range site with certified calibrated equipment. The compliance house will produce documentation to be reviewed by the regulatory agency. An example of a compliant house is UL and LS Research in the USA and TUV in Europe. Some large companies have test departments that have been certified by a regulatory agency and therefore, can do in-house testing to produce documentation to submit for an ID number. Needless to say, such a department is costly and must be justified. The selection of a compliant house sometimes called a test house is very important. An experienced compliance house will not only know local regulations but must also be knowledgeable in world regulations. The correct regulation must be chosen to qualify the product for the market of interest.

World Wide Regulatory Agencies

Even though the ISM product itself will not need a license, proper documentation must be submitted to the governing regulatory agency for permission to operate the product in the area of interest. The following is a list governing agencies with typical frequencies:

USA

Federal Communications Commission, (FCC)

CFR 47 Parts 15.35, 15.205, 15.209, and 15.231.260-470MHz

Part 249, 902-928MHz

http://www.access.gpo.gov/nara/cfr/waisidx_01/47cfr15_01.html

European Compliance

Radio Devices in Europe have to meet the Radio and Telecommunications Terminal Equipment (RTTE) Directive in order to be placed on the EU market. In order to operate, they also have to meet spectrum regulations in the EU member state concerned. Regarding compliance, the equipment is presumed to comply if it is built with a Harmonized Standard (e.g. EN 300 220). The manufacturer self-certifies and produces a "Declaration of Conformity". European Regulatory Commission (ERC) document CEPT/ERC/70-3 defines regulatory operation at 433MHz along with 838MHz. EN300 220 define test methods and signal level limits.

More information on this is available from:

http://www.etsi.org

http://portal.etsi.org/radio/RTTEDirective/RTTEdirective.asp

United Kingdom

Dept. of Trade & Industry, (DTI), MPT 1340 418MHz and 433.92MHz

Germany

Fernmeldetechnisches Zentralamt (FTZ), FTZ 17 TR 2100 433.92MHz

France

National Telecom. Research Center, (CNET)

Terminals, Procedures and Applications Group, (TPA)

Specification Tecnhnique (ST)

ST/PAA/TPA/AGH/1542 223.5-225.0MHz and 433.92MHz

Canada

Dept of Communications, (DoC)

Telecom Regulatory Service

Radio Standard Specification (RSS)

RSS-210, 260-470MHz and 902-928MHz

South Africa

403.916 and 411.6MHz

Australia

Dept of Transport & Telecommunications, (DTC)

ECR60, 303.825MHz and 318MHz

Australian Communication Authority (ACA), AS-4268.21995

http://www.aca.gov.au/legal/license/class/lipd.html

Israel

Ministry of Communications, Engineering & Licensing Div. 325MHz

Japan

Ministry of Posts & Telecommunications, (MPT), 322MHz

Asia-Pacific Economic Cooperation Telecommunications and Working GroupAPEC TEL WG at: http://www.apectelwg.org/apec/alos/osite_1.html

Hong Kong

Post Office, Telecom. Branch Telecom.

Order 1989, Sec 39, Chap. 106 314MHz.

For other countries go to the Asia-Pacific Economic Cooperation Telecommunications and information Working Group's (APEC TEL WG) website at: http://www.apectelwg.org/apec/alos/osite_1.html.

Brief Description of CFR47 Part 15 and ETSI 300-220

The following section will discuss USA and European regulations; specifically, CFR47 Part 15 paragraph 231 and ETSI 300-220 for USA and Europe respectively.

CFR47 Part 15

CFR47, Part 15, Paragraph 231 Section (a) and (b) will be used to describe the FCC requirements used by a compliance house. This includes modes of operation and power levels allowed for intentional radiators to be used in the ISM market.

Modes of Operation and Allowed Mode of Operation:

- Command or control signals such as garage and automotive entry.
- Codes that identify the particular transmitter which is useful to allow the use of several transmitters at one frequency.
- Emergency transmissions; this type of transmission are allowed during the duration of the emergency.

Operation Modes Not Allowed

- Transmission of voice and video.
- RF controls of toys.
- Continuous transmission of data.
- Periodic transmission at regular and pre-determined time intervals.

To comply with the above aforementioned conditions the following further details the modes of operation allowed:

- A manually operated transmitter must be automatically deactivated within five seconds of being released from operation.
- Automatic activation of a transmitter must cease operation within five seconds of operation.
- Polling is restricted to one second of transmission duration per one hour for each transmitter.

Operation Modes in Conclusion

When designing the operation of the transmitter such as the TX112-1, and when activated manually, the transmission must stop radiating within five seconds of activation. If transmission has an automatic mode then operation must stop within five seconds after activation. Periodic transmission, for example, must not operate as a beacon and is not allowed unless the rate of this periodic beacon transmission is not more than one second for every hour. The important thing to remember is to not transmit in a continuous mode and to transmit at a compliant RF power level allowing the sharing and use of a frequency channel by other users. If it is acceptable to operate at a low power level then more flexibility is allowed in your mode of operation though the use of other sections of Part 15. It is best to consult with an experienced compliant house to determine which section is applicable for the product and its advantage when using the chosen mode of operation.

Power Level of Intentional Radiators

The power level of the TX112-1 when used as an intentional radiator follows two categories governing transmitters, these being periodic transmitter and non-periodic (or continuous) transmitters. For the TX112-1, the following power levels pertain to ISM band of operation from 260MHz to 470MHz described as periodic categories:

1. Transmit power is measured in terms of field strength, measured at a distance of three meters from the radiating antenna. The maximum transmit power level ranges from 3750µV/meter to 12500µV/meter for the frequency band of 260MHz to 470MHz, respectively.
2. Maximum harmonic and spurious levels must be 20dB below the transmit carrier. The maximum spurious power level ranges from 375µV/meter to 1250uV/meter for the frequency range of 260MHz to 470MHz, respectively.
3. The bandwidth of an emission, Occupied Bandwidth, (OBW) shall be no wider then 0.25% of the center frequency of the transmit carrier. Bandwidth is defined at points 20dB down from the peak of the modulated carrier with a RSBW at 100kHz at 1.5MHz to 2MHz span.
4. Emissions shall be measured up to the tenth harmonic of the fundamental carrier frequency for the intentional radiator.

Restricted Bands

Even though the above implies operation from 260MHz to 470MHz, the allowed FCC frequency range is from 40MHz to above 470MHz with restricted frequency bands described in CFR47 Part 15. Refer to Paragraph 205 of this regulation for what are the restricted bands of operation.

Emission Limits of Intentional Radiators

Random or Periodic Intentional Radiators

The following table lists maximum FCC radiation levels for intentional, (fundamental) and non-intentional, (spurs and harmonics) covered under Paragraph 231 Section (b). The calculation involves a linear interpolation from 260MHz to 470MHz that include the operating frequencies of the MICRF112, 300MHz to 450MHz.

Frequency (MHz)	RAD. PWR@3m Max. (µV/meter)	Harmonic Level (µV/meter)
260	3750	370.00
300	5417	541.67
303.85	5577	557.71
315.00	6042	604.17
387.00	9042	904.17
390.00	9167	916.67
400.00	9583	958.33
418.00	10333	1033.33
433.92	10997	1099.67
470.00	12500	1250.00

Table 1. Maximum Levels for Random or Periodic Intentional Radiators

Non-Periodic or Continuous Transmission

The following table list power levels that can be operating in a non-periodic or continuous mode as described in Paragraph 231, Section (e).

Frequency (MHz)	RAD. PWR@3m Max. (µV/meter)	Harmonic Level (µV/meter)
260	1500	150.00
300	2167	216.67
303.85	2231	223.08
315.00	2417	241.67
387.00	3617	361.67
390.00	3667	366.67
400.00	3833	383.33
418.00	4133	413.33
433.92	4399	439.87
470.00	5000	500.00

Table 2. Maximum Levels for Non-Periodic or Continuous Intentional Radiators

Frequency (MHz)	Fundamental Limit (µV/m@3m)	Fundamental Limit (dBµV/m @3m)	Harmonic Limit (µV/m @3m)	Harmonic Limit (dBµV/m @3m)
315.0	6042.7	75.6	604.18	55.6
433.92	10997	80.92	1099.67	1099.67

Table 3. CFR47 Part 15, Para 231, Section (b), Emission Limits in µV/m to dBµV/m at 3 Meters

Paragraph 205 and 209

The following table list the power limits not restricted by Paragraph 231. For a detailed description refer to Section 205 and section 209 of CFR47 Part 15.

Frequency (MHz)	3m Limit (µV/m)	3m Limit (dBµV/m)
30-88	100	40.0
88-216	150	43.5
216-960	200	46.0
960-24,000	500	54.0

Table 4. RF Emissions Limits as Described in CFR47 15.209 and 15.205

Example calculation of converting µV to dBµV/meter:

E = 100 uV/meter

dBµV/meter = 20 log(E/(1x 10^-6)

E = 40 in dBµV/meter

European Regulations for Intentional Radiators

European Standard, EN-300-220

The following discussion is a brief description of European requirements for releasing a transmitter similar to the TX112-1. As a reference, the following regulations may be referenced as part of the European Regulations:

Commission (ERC) document CEPT/ERC/70-03. This document defines the regulations for operation at 433MHz and 868MHz. Test methods and signal level limits are defined in ETSI-EN-300-220. The summary of regulations can be based upon system requirements at 433MHz, no specified channel spacing for a wide band transmit signal. Wideband is defined as a transmitter band with greater then 25kHz.

Conditions:

- Class A operation from 433.050MHz to 434.790MHz.
- No system channel spacing specified.
- Tests are performed with a spectrum analyzer set for RBW = 100kHz and,
- VBW = 10kHz.
- Modulation is AM/ASK.

Regulations:

- Maximum power allowed is 10mW (conducted and referenced to 50Ω).
- When the transmitter is operational, the maximum spurious (and harmonic) emission limit is –36dBm (conducted and referenced to 50Ω). Table 5 lists frequencies with corresponding limits.
- When the transmitter is stand-by mode, the maximum spurious (and harmonic) emission limit is –57dBm (conducted and referenced to 50Ω).
- Frequency Error (transmit center frequency) is not regulated in systems with no specified channel spacing (however, the modulated signal bandwidth must remain inside the band limits of 433.050MHz to 434.790MHz).
- Transmitter bandwidth is greater then 25kHz, but less then the width of the 433.050MHz to 434.790MHz band.
- The transmitter shall either stay on frequency or cease operation when the power supply level is reduced from the operating voltage to zero.

Frequency	47MHz to 74MHz 87.5MHz to 118MHz 174MHz to 230MHz 4770Mhz to 862MHz	<=1000MHz	> 1000MHz
Power Level	4.0nW	250Nw	1.0uW

Table 5. European Limits

Note:

4.0nW = - 53.98dBm;

250nW = -36dBm;

1.0uW = -30dBm

Critical Tests of Major Interest

When trying to pass a compliance test, the following RF measurements will be of major interest. Test criteria become a little more complicated for spread spectrum which is not within the scope of Micrel's MICRF112. Depending upon what country the unit is to be marketed the specific values may be different and are specifically detailed within the countries regulatory standard.

1. Fundamental Power.
2. Fundamental Frequency Accuracy.
3. Occupied Bandwidth.
4. Harmonics.
5. Spurs.

The above measurements are a function of the following:

1. Fundamental frequency of operation.
2. Input voltage, V_{DD} to the MICRF112.
3. Output matching network.
4. Antenna configuration.

hbwhelp@micrel.com or (408) 955-1690

Preparing Your Product as a Marketable RF Device

A RF device about to enter the RF market requires preparation so as to minimize time market and cost. The MICRF112 alleviates much of the RF design work, but proper planning is still needed.

RF Design Considerations:

1. Consider the type market the product will be placed in: consumer, commercial, industrial etc.
2. Product requirements:
    - Industry, scientific or medical,
    - RF Frequency of operation and mode of operation and,
    - Prepared samples to give to a compliance house.
3. Regulations of interest, obtain regulations of place or places of operation.
4. Be prepared to pre-test a device by using in-house test equipment. The experienced engineer should be able advise which test will be needed to enter a product into the public market.
5. Find an experienced compliance house to advise the house engineer on what the specifications the product will need to meet. A compliance house specializes in knowing worldwide regulations with experience on what tests need to be done on your product. The compliance house will require the following:
    - The market of interest.
    - Functional objective and,
    - Functional description of operation.
6. Be prepared to make adjustments to the product being tested. For example, adjusting transmitted power if power exceeds the fundamental power limit.

With this information, the compliance house will advise what specifications will need to be met. It is still the manufacturer's responsibility to specify the operating conditions that the product will be subjected too.

The Process and Expense for Compliance Testing

Modification or Upgrade of a Product

After being issued an FCC ID Number, modification or an upgrade of a product may necessitate retesting by a compliance house. If the modification can be shown not to affect safety while still maintaining original compliance with in-house testing, a new identification number may not be required. Consulting with a compliance house is advised.

Pre-Compliance and Full Compliance Testing Under CFR47, Part 15

As mentioned previously, the objective of this application note is to demonstrate the process of passing compliance testing using the TX112-1. Part of the design phase is to understand the regulations in the desired market place. This not only includes regulations for RF transmissions but regulations for the safety of the user. To submit a product that produces RF transmissions the following general steps are recommended:

1. Understand the regulations that the product is subject to.
2. Design the product with regulations in mind, (example, Periodic or Continuous Mode of Operation).
3. Perform in-house pre-testing using calibrated RF equipment:
    - Spectrum Analyzer.
    - Calibrated antenna is the corresponding frequency band.
4. If in-house pre-testing also known as pre-compliance can not be done, submitting the unit to a compliance house for a pre-test is recommended.
5. If the unit passes pre-compliance, proceed to full compliance. If unit fails, correct the discrepancy and resubmit for full compliance testing. Some compliance houses will allow adjustments during the test therefore, be prepared to make proper adjustments.

The objective of a pre-compliance test is to enable a lower cost pre-test phase, correct failing measurements, and to proceed to compliance testing. If there is confidence that the unit will initially pass, then proceed to a full compliance test. An in-house pre-test may provide the confidence to initially submit for full compliance testing as discussed in the proceeding sub-section.

In-House Pre-testing of the TX112-1

The following lists a number of methods typically preformed to pre-test a design prior to submitting it to a compliance test house:

1. Hire a consultant experienced in compliance testing.
2. In-house testing using proper RF equipment such as a spectrum analyzer and antennas that cover the RF spectrum of interest.
3. Use of a reference design such as the TX112-1 with the understanding that final adjustment will need to be done during compliance testing.

In this application note, a reference design, as mentioned in Step 3, will be used.

The use of TX112-1 reference design requires that the designer use a specific printed circuit board layout with its appropriate list of parts. This is an efficient way to cut cost and to decrease time to market. The TX112-1 has gone through 315MHz and 433.92MHz FCC compliance testing and can be used as a starting point. The documentation describing the TX112-1 is a good reference point to start from but it is the responsibility and good practice of the user to perform thorough testing to pass compliance of the desired end product. Any modifications, such as modulating schemes and antenna revisions, will require more in-depth pre-testing.

Preparing for Pre-Testing

Accurate in-house pre-testing will be difficult but possible. A test set-up is described as the minimum test set-up which to perform comparative emission tests. A comparative emission test consist of using a known transmitter that has passed a compliance standard. Use this known good transmitter to diagnose a failed unit. Compare RF spectrum levels by using a spectrum analyzer.

Test Equipment

The following is a list of test equipment that is needed to do a pre-test:

1. Spectrum analyzer.
2. Amplifier, 100MHz to 5GHz, 20dB gain, -60dBm input.
3. Antenna to cover the 100MHz to 5GHz spectrum.
4. Insulating tripod to support the antenna.

Working Area for Pre-Testing

1. Unrestricted floor space allowing for a three meter range test including one meter radial space of the antenna and product to be tested.
2. No extra electronic equipment should be left in the near vicinity of floor area resulting source of extraneous emissions and or reflections.
3. Floor area to be covered with a ground plane of copper or aluminum.
4. Working table should be insulated with wood or plastic; this will only need to support the system.
5. Minimize surrounding objects that will cause reflections resulting in accuracy errors. Maintain consistent placement of the unit under test to help produce consistent results.
6. Consistent orientation of the antenna is important. Orienting the antenna horizontally will polarize is such a way as to reduce errors due to ground reflections.

The above issues would be considered the minimum requirements. Keep in mind that the set-up is for relative measurements and that consistency is important. Orientate the unit under test for maximum power seen by the spectrum analyzer. Use a unit that has passed compliance test as a reference and as a comparison with the unit to be submitted. Radiated measurements made in this non-calibrated setup should have a 10dB to 15dB margin to maintain a confidence level in passing a compliance test.

Preparing the Unit for the Compliance House

The test house will require a sample of the product that operates as described in CFR47, Part 15 Paragraph 209 and 231. Also required will be the capability of placing the product in various modes of operation for example Standby, Mark, Space and Burst Mode. Also needed is the capability to turn power of the unit off and on. This is to see if and transmission occurs during power up which could include unintentional spurs.

Relaxation Factor as a Function of RF Modulation

As a manufacturer, typically, it is desired to achieve the maximum range by transmitting maximum output power allowed by the regulatory agency. For FCC testing, the in-burst mode (transmitting a set of bits at a duty cycle) is an advantage in that the compliant test house will be allowed to use a relaxation factor. Relaxation factor is a function of the modulation scheme therefore, a plot describing how one is modulating the RF carrier must be provided to the compliance house. For the TX112-1 Test Set, it is the encoder output to Micrel's MICRF112. An example is shown in Figure 1. The advantage in the relaxation factor is that it allows for a higher peak power while still maintaining the average limit. This relaxation factor is not used or allowed for ETSI compliance.

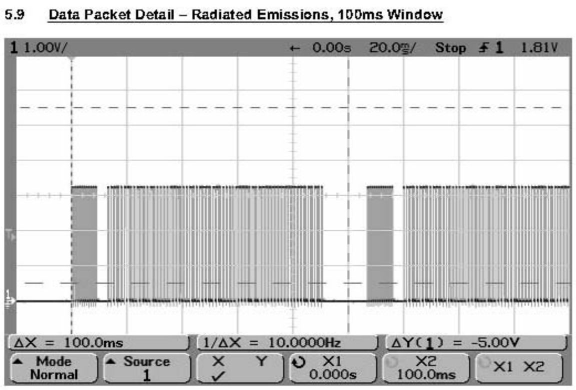


Figure 1. Encoder Output to MICRF112 ASK Input

Even though this application note will present documentation of a design that has passed FCC and ETSI standards, one's end product has to be submitted for retest to qualify for an ID number. Because of variations of material, including FR4 PCB material and variation of components by the component manufacturer, performance may vary. Also keep in mind that different modulation schemes, which are specific to the end operation, will produce different RF transmission parameters such as average output power.

TX112-1 Power Calculations

Output power of the TX112-1 can be adjusted by adjusting the series resistor, R7. Maximum output power is available when this resistor is zero ohms. Figure 2 is an example of the output matching and filter network. Even though the loop antenna for the reference board, TX112-1 is an inefficient antenna, the power output is capable of exceeding the FCC power limits. Therefore, R7 will need to be used to decrease the radiated power level, which not only includes the fundamental frequency but the harmonics frequencies.

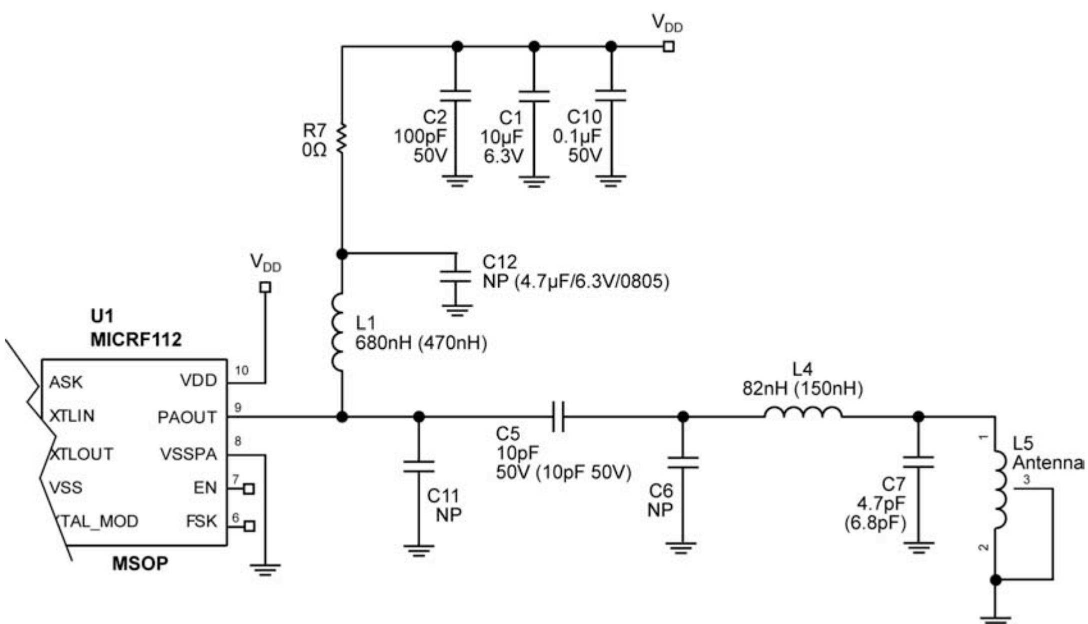


Figure 2. Typical MICRF112 Output Stage

Radiated Transmitter Output Power Calculation

CFR47, Part 15, paragraph 231 give values in micro-volts per meters at a range of three meters. When a compliance house tests a transmitter, the results are typically given in micro volts per meters from the device under test, (DUT) to the calibrated antenna. The calibrated antenna is monitored under a 50Ω system. As an example, to calculate the power from a 0dB gain transmitter antenna to a 0db gain receiver antenna the following equation can be used:

Given:

1. The electrical field strength, E = 10977 μV/meter, R = 3 meters between transmit antenna and receiver antenna.
2. Antenna gains or transmitter and receiver = 0dB or gain of 1.

Question: What is the Power Output of the Transmitter?

The following is an example of estimating what the output power of the transmitter into its radiating antenna:

Field Strength to Power in dBm

E = 10977 μV/m, Measured Field Strength in Volt per Meter

r = 3 meters, distance between transmitter and received antenna.

Ptx = (E*r)^2/30, E = Radiated Power in volts per meter.

Ptx = 3.615 * 10^-5 watts

Ptx_dbm = 10 * log(P_tx/.001)

Ptx_dbm = -14.419 dBm, Power output of the transmitter in dBm

The gain of both antennas has to be taken in account if a transmitter antenna other than an antenna of 0dB gain is used. For instance, a loop antenna, which has a gain much lower than 0dB would radiate much lower power then a monopole antenna. Another way to view this is that more transmitter output power is needed to receive the same level when using a loop antenna.

Compliance Testing at the System Level

The previous discussions have focused on the RF section. Figure 3 shows the complete system that will be tested for FCC compliance. This product consists of two boards:

- TX112-1-433.92MHz, Transmitter Assembly.
- TXBB1, Controller Assembly.

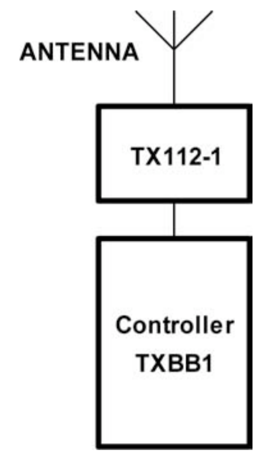


Figure 3. System to be Tested

The main focus will be on the transmitter assembly. The main function of the controller board is to set-up the environment for the TX112-1 board, Figure 5. This includes the modulating data signal for the RF carrier and the regulated input voltage, 3.3V. Figure 4 and Figure 6 show schematics of the transmitter board and controller board respectably. Table 6 show values for 315MHz, 390MHz, 415MHz and 433.92MHz and they are critical to meet FCC compliance. For any other frequencies, contact the Micrel RF Applications Department.

Frequency	R7	L1	C5	L4	C7
315MHz	680Ω	470Nh	10pF	150nH	6.8pF
390MHz					
415MHz					
433.92MHz	1000Ω	680nH	10pF	82nH	4.7pF

Table 6. TX112-1 Output Configuration

The TX112 RF output section has been designed to meet FCC compliance with the following guidelines:

1. Optimize output power.
4. Optimize efficiency for long battery life.
5. Minimize harmonics.
6. Minimize spurs.

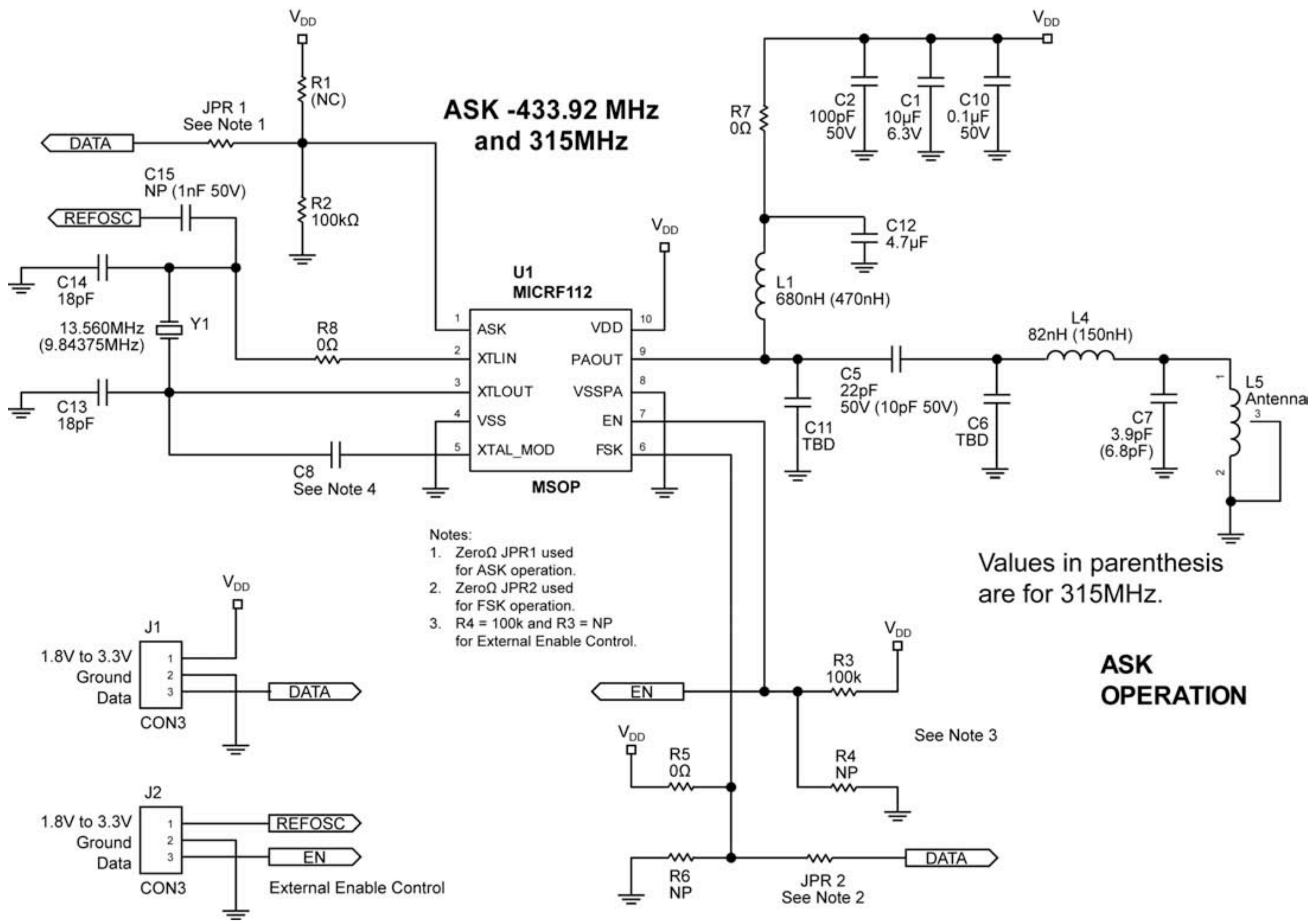


Figure 4. TX112 Schematic

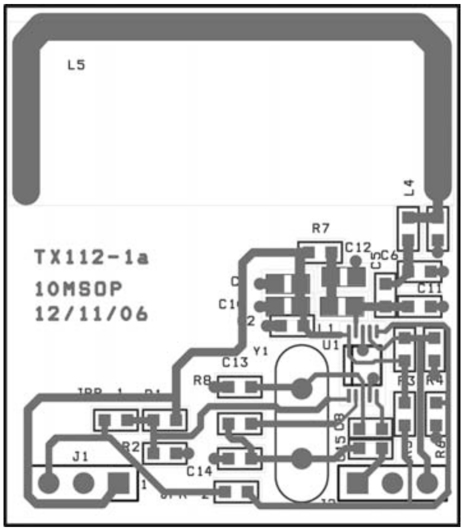


Figure 5. TX112 Assembly

TX112 Test Board Description

The core of the TX112-1 Test Board is the transmitter IC device and its ease of operation. A brief description follows: The benefits of the MICRF112 are in three areas: power delivery, operating voltage, and operating temperature. In terms of power, the MICRF112 is capable of delivering +10dBm into a 50Ω load. This power level enables a small form factor (small inefficient antenna) such as a key fob transmitter. In terms of operating voltage, the MICRF112 operates from 1.8V to 3.6V and -40ºC to +125ºC. For a detailed description, review the MICRF112YM datasheet located at the Micrel website: http://www.micrel.com/page.do?page=/product-info/products/micrf112.jsp

Controller

The Controller board supplies to the TX112-1 the supply voltage and the digital signal to modulate the carrier. The Controller board is not the subject of this paper and of meeting compliance but in a typical product release such as a key fob it would be viewed as part of the overall system under compliance testing.

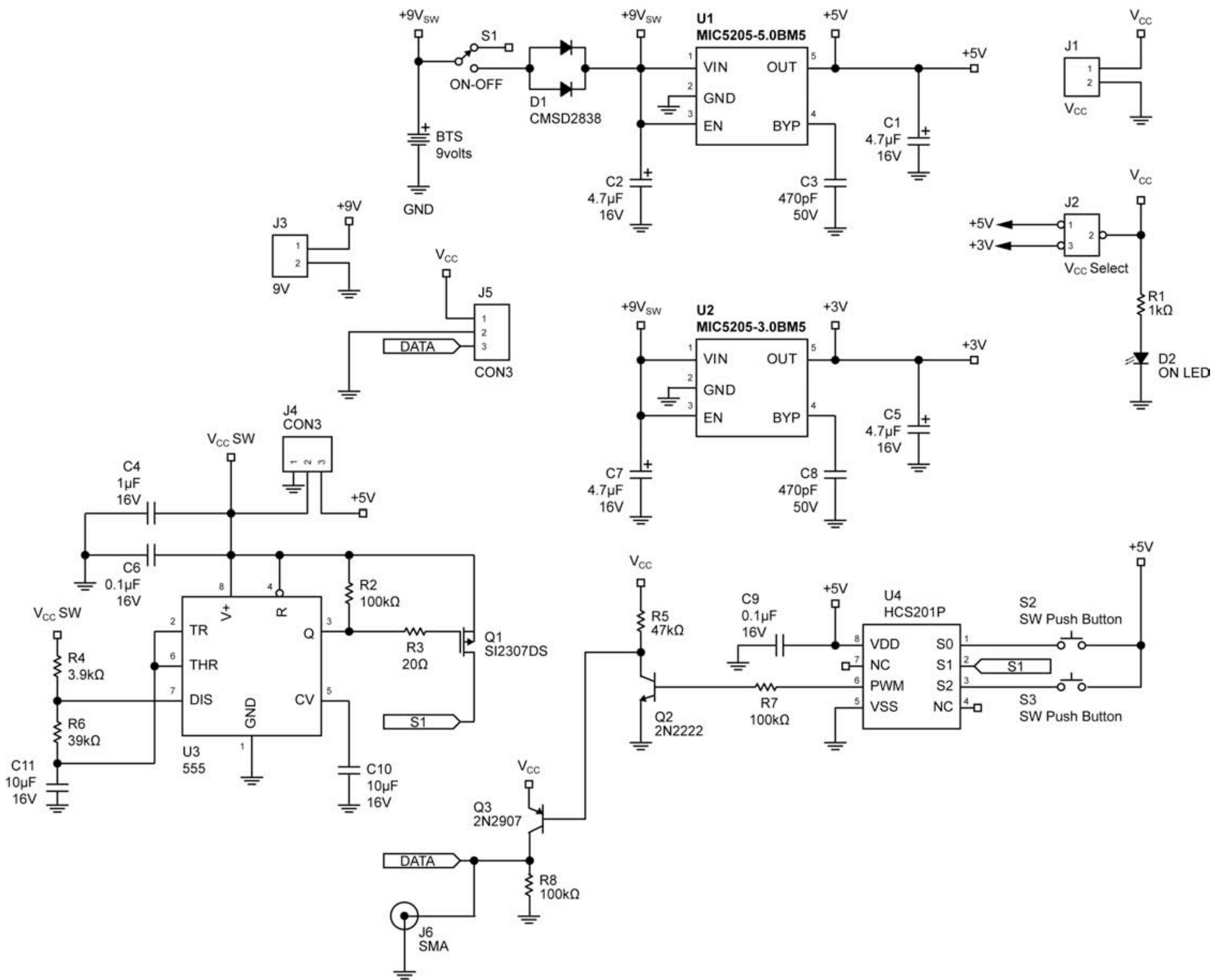


Figure 6. Controller for Transmitter Demo Board

Power Calculations Using an Isotropic Antenna

In the sub-section, "Radiated Transmitter Output Power Calculation" an example was given in estimating the output power of the transmitter as function of the desired electric field, µV/meter. The equation used in the previous section takes into account antenna pattern factors for both transmitting and receiving antennas and factors effecting incident and reflected power.

Transmitter Power Calculations

The following section will detail and calculate the output power of a transmitter using an ideal isotropic antenna. A comparison with the previous calculation indicates that at least 3dB more power is achieved when not taking into account the various factors that effect reception between the transmitter antenna and receive antenna.

Power Calculations using an Isotropic Antenna

- Antenna Gain, G = 1, Isotropic Antenna used for both transmitter and receiver
- E = 10977 uV/meter, FCC limit at 433.92MHz.
- f = 433.92MHz, frequency of interest
- _ _ = (300*10^8) / f, quarter wavelength
- A_e = effective area of received antenna
- S_rx = Average Power Density at the receiver
- Ptx' = Power at transmitter
- _=377_, intrinsic impedance of free space

S_rx = E^2/2*_

S_rx = 159.8*10^-9 watts/meter^2

S_rx = Ptx'/Area

Area at 3 meters range = 4 * π * r^2

Ptx' = S_rx * Area = 18.07uW

Ptx_dBm' = -17.43 dBm, transmitter power

The above results show that the previous calculated power is less than Ptx' by at least 3dB. This indicates that less power is needed to achieve E = 10997 µV/m when the transmission factors are not taken into account, including antenna efficiency.

Antenna Efficiency

Typical antenna efficiencies such as the loop antenna used on the TX112-1 can range from 10% at 315MHz to 30% at 433.92MHz. Therefore, the power needed when using a loop antenna will be much higher to achieve E = 10977 uV/m^2 as compared to an isotropic antenna.

Receiver Power Calculations

The following is an example of calculating the power received into the receiver using an isotropic antenna having a gain of 0 dB, G = 1.

E = 10977 uV/meter^2, FCC allowed limit at the receiver antenna.

R = 3 meters, range from source, (transmitter to receiver).

S_rx = E^2/2*_

A_e = _^2/4*π*G, Antenna Effective Area with G = 1

Prx = S_rx * A_e

Prx = 6.079 nano Watts

Prx_dBm = -52.16 dBm

As in the previous example, the above calculations are done with an isotropic antenna. Antenna efficiency such as for a loop antenna must be considered when using anything other then an isotropic antenna.

Three-Meter Test Results from a Compliance House

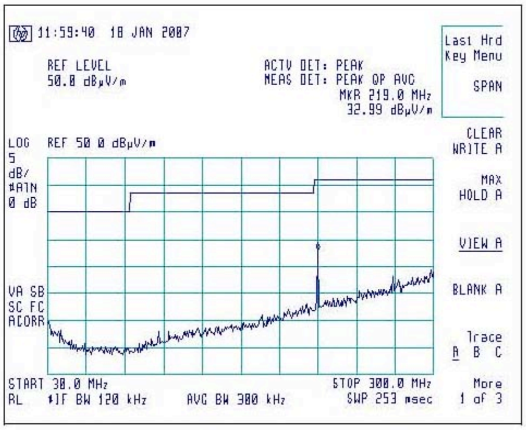
The following are plots for three meter measurements of the TX112-1a for FCC compliance. Measurements are taken by a certified compliance house, LS Research. A pre-compliance measurement was first taken to point out any obvious "over the limit" violations such as excessive fundamental or harmonic power levels. With these measurement corrections if necessary are done before proceeding and setting up for a full compliance test.

Figure 7 is a photo of one example of the placement of the Device under Test shown by permission of LS Research, Cedarburg, Wisconsin.

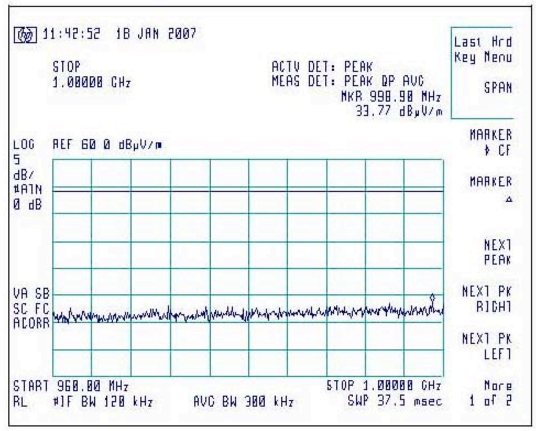
Figure 7. DUT Orientation Example

RF Spectrum Plots for FCC Compliance

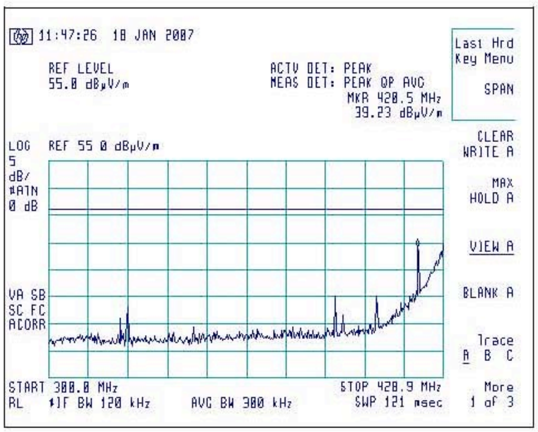
30-300 MHz



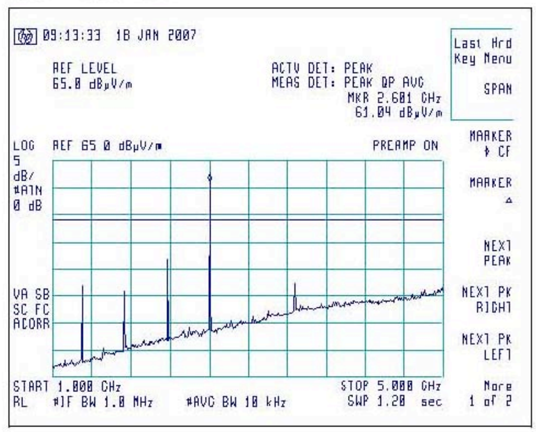
960 - 1000 MHz



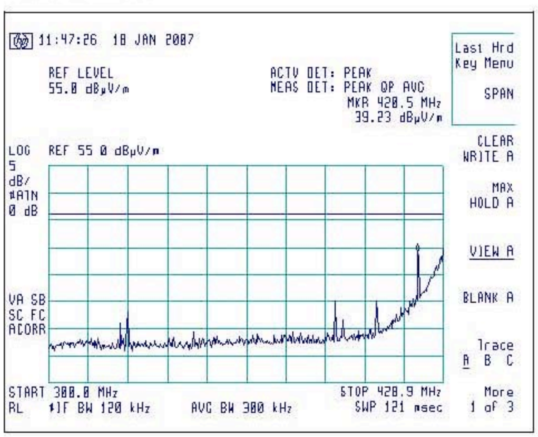
300-428.9 MHz



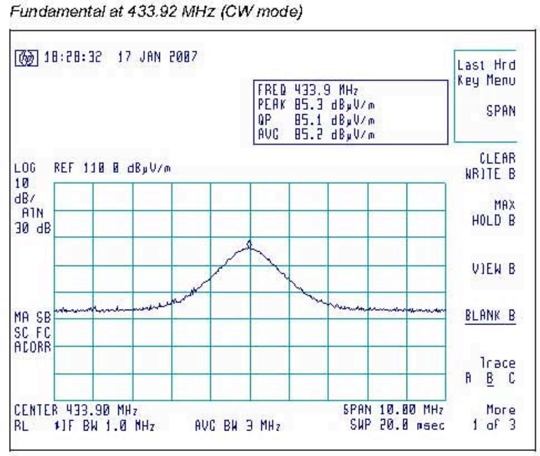
1000 - 5000 MHz



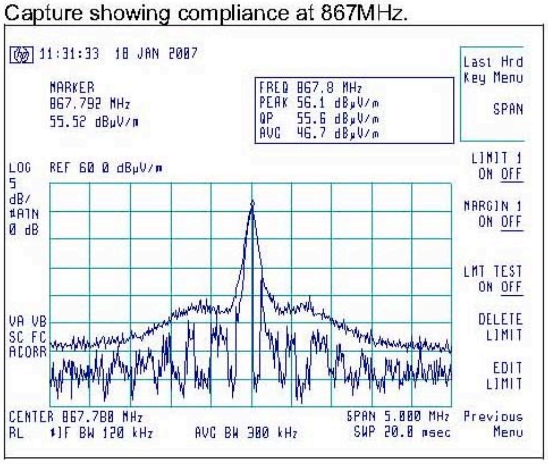
300-428.9 MHz



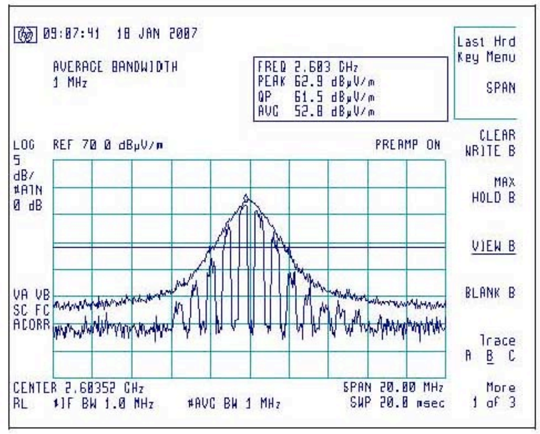
Fundamental at 433.92 MHz (CW mode)



Capture showing compliance at 867MHz.

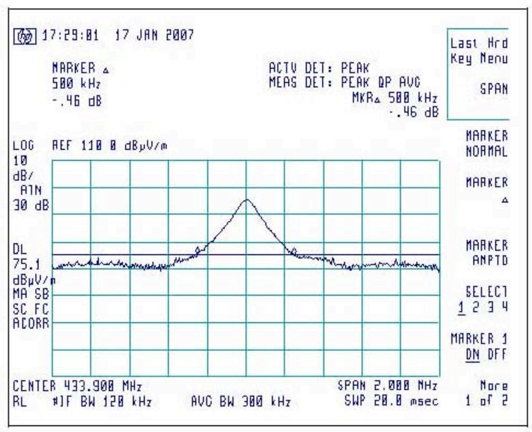


Capture showing compliance of 6th harmonic.



Occupied Bandwidth

Measurement of the Occupied Bandwidth was made with the EUT in continuous transmit mode, with typical modulation as applied by the EUT circuitry.



ETSI Pre-Testing

The TX112-50-ETSI is a 50Ω board used to perform ETSI conductive pre-testing at 433.92MHz. After pre-testing, the board was submitted to a compliant house for ETSI testing. Results with design documentation are available upon request. The objective is for the evaluation board to be compliant to ETSI EN 300 220. Figure 8 shows the schematic with finalized component values. A 50Ω conductive measurement is required to perform ETSI testing. Emphasis was placed on low spurious and harmonic values as required by EN 300 220. Complete documentation is available from the Micrel RF Applications Department. See sub-section “European Regulations for Intentional Radiators” and Table 5 for detailed ETSI RF limits.

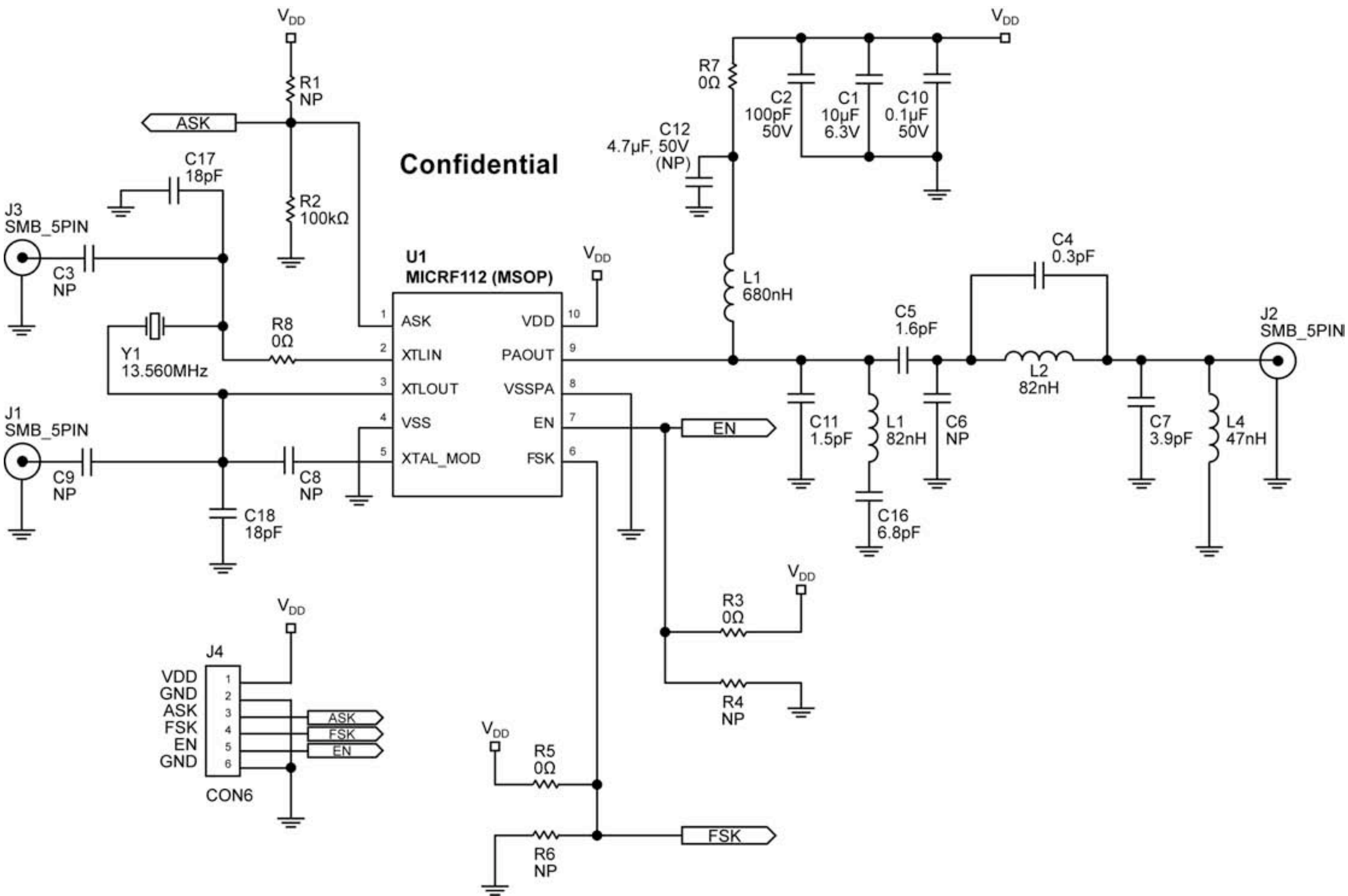
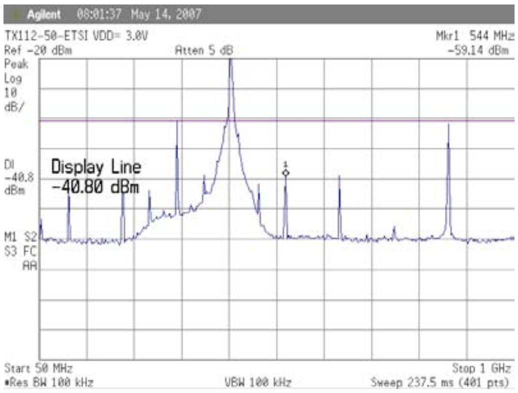


Figure 8. MICRF112 ETSI Evaluation Board

ETSI Pre-Testing, Conductive RF Measurements

The following are examples of RF spectrum plots taken during in house ETSI pre-testing. Full compliance testing was performed by a qualified compliance house. After verifying limit levels the system was submitted to a compliance house for ETSI approval.

Span from 50MHz to 1000MHz

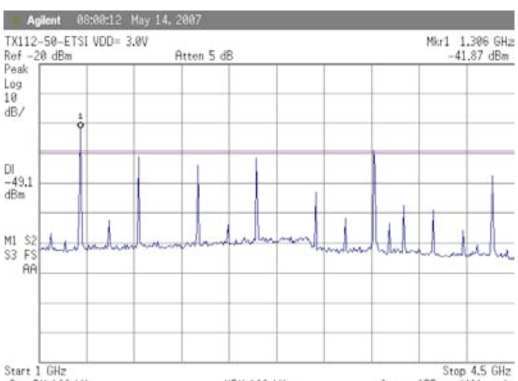


Note:

Marker at 650MHz at -59.14dBm, limit = -54dBm.

Display Line at -40dBm, limit = -36dBm.

Span from 1GHz to 4.5GHz

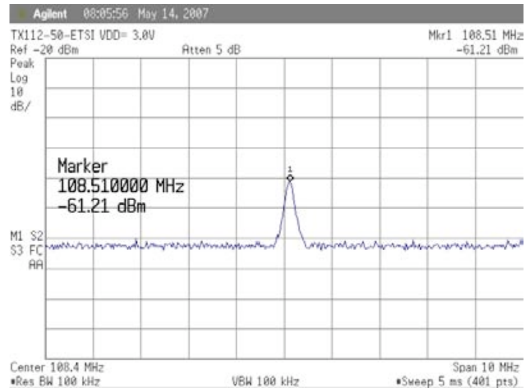


Note:

Marker at 1.306MHz, -41,87dBm, limit = -36dBm.

Display line at -49.1dBm, limit -36dBm.

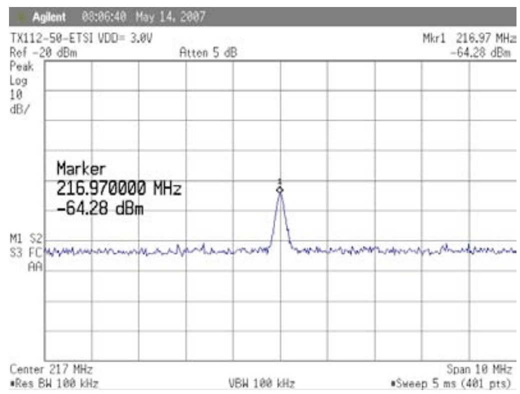
108.4MHz Sub-harmonic



Note:

Marker at 108.51MHz, -61.21dBm, limit = -53.98dBm.

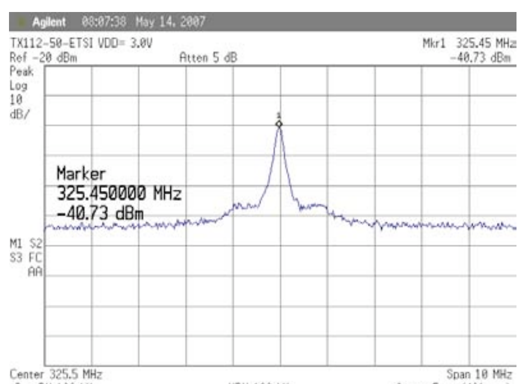
Sub-harmonic at 216.97MHz



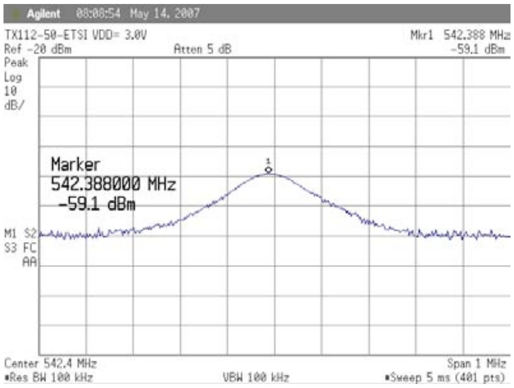
Note:

Marker at 216.97MHz, -64.28dBm, limit = -53.98dBm.

Spur at 325.45MHz

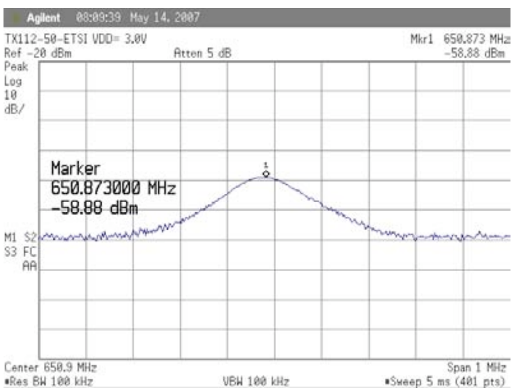


Spur at 542.388MHz



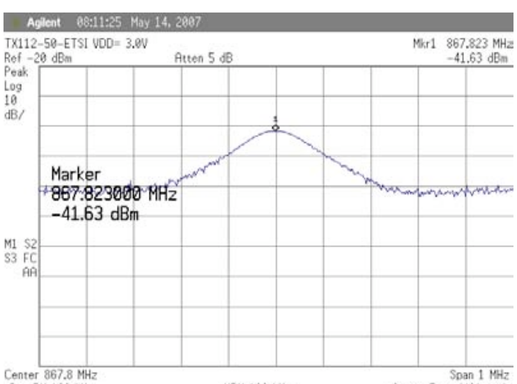
Note:
Marker at 542.38MHz, -59.1dBm, limit = -53.98dBm.

Spur at 650.87MHz



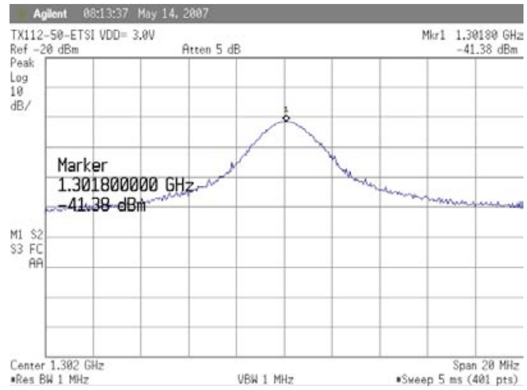
Note:
Marker at 650.87MHz, -58.88dBm, limit = -53.98dBm.

2^{nd} Harmonic at 867.82MHz



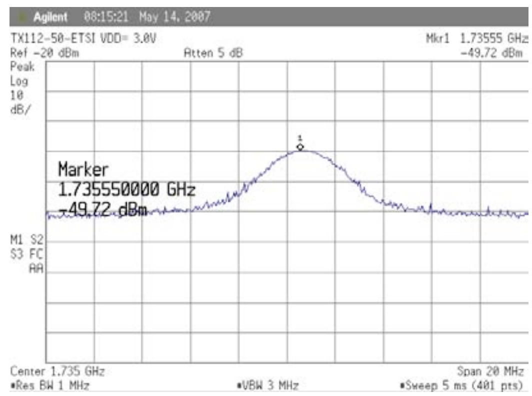
Note:
Marker at 867.823MHz, -41.63dBm, limit = -36dBm.

3^{rd} Harmonic



Note:
Marker at 1.3018MHz, -41.38dBm, limit -36dBm.

4th Harmonic

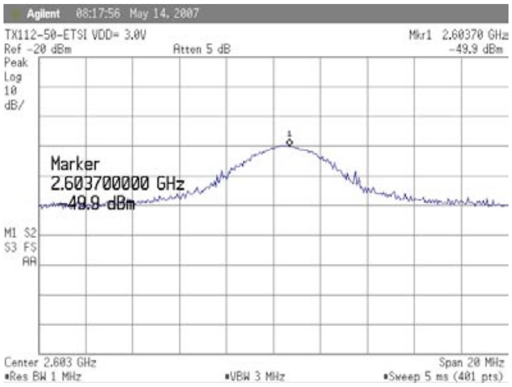


Note:
Marker at 1.7355GHz, -49.72dBm, limit = -36dBm.

5^{th} Harmonic

Note:
Marker at 2.1695GHz, -51.8dBm, limit -36dBm.

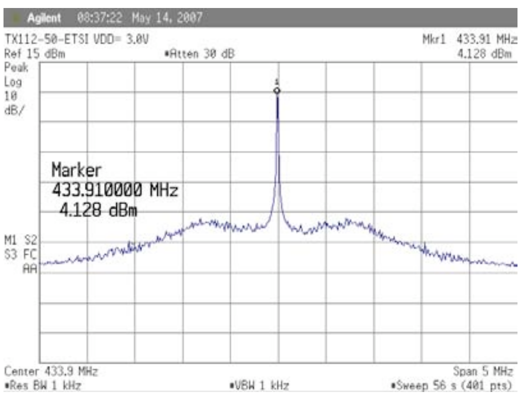
6th Harmonic



Note:

Marker at 2.6037GHz, -49.9dBm, limit at -36dBm.

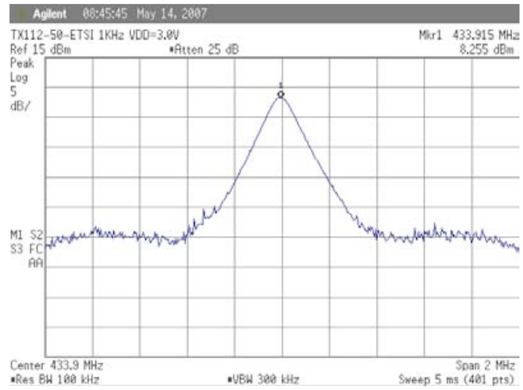
Fundamental, 433.92MHz with RSBW = 1kHz



Note:

Marker placed at 433.92MHz.

Fundamental, 433.92MHz with RSBW = 100kHz, 1kHz Baud Rate



Note:

Marker at 433.92MHz, 8.23dBm, limit = 10dB.

Frequently Asked Questions (FAQ)

1. Q: What is the difference between intentional and non-intentional radiation?

A: An intentional radiator, typically known as a transmitter, radiates a controlled frequency. A non-intentional radiator radiates unwanted RF frequencies such as spurs and harmonics of the later. Measures must be taken to control the levels.

2. Q: After receiving an FCC ID number must I resubmit for qualification if the product is modified?

A: After receiving certification that the tested unit has been accepted by a regulatory agency, any modification typically means re-qualification. This depends upon the type and level of modification such as antenna changes to modulation to carrier changes. Consult with a compliance house to see if in house re-qualifications can be made and what are the necessary procedures.

3. Q: Why is sharing air ways so important in the ISM band.

A: One of the benefits of the ISM band is that a license is not required. However, the use of the frequencies must be done in an organized and regulated manor. This not only minimizes the chance of being interfered by other signals, but promotes safety. An example as a consequence of unregulated transmission (as in some countries) happened when an automobile traveled through an intersection and ceased to operate.

4. Q: Is a radio receiver considered an intentional radiator?

A: Even though RF receivers are considered non-intentional radiators, compliance testing still needs to be done. Most of today's newer receivers have low reradiated emission from the antenna port. Therefore, meeting compliance is typically not an issue. A common receiver dating back to the 1920's is the super-regenerative receiver, which has high levels or re-radiation from the antenna port. Also, receivers need to go through other tests such as susceptibility and immunity test.

5. Q: What are the typical RF tests that could be issues in qualifying a product?

AN:

- Fundamental power levels
- Occupied Bandwidth
- Spurs
- Harmonics products of the fundamental operating frequency
- Unintentional radiation while turning your product off and on

All the above parameters are described by a regulatory agency's standards, even to extent of describing the setting and placement of the test equipment and orientation of the device under test**.**

6. Q: What is Periodic Mode Operation?

A: Mode of operation that has a prescribed number of burst periods and off period of transmission.

Examples: Garage door openers, automotive remote keyless entry.

7. Q: What is Continuous Mode of Operation?

A: Mode of that is continuous in operation that is beyond the allowed time period specified by Paragraph 231, Section (a). To operate in this mode, Paragraph 231, Section (e) may be applicable.

8. Q: What is Random Mode of Operation?

A: Transmission of a signal that is not done in a pre-defined or pre-determined fashion. An example is when transmission is achieved with the use of a push button. Example: Garage door opener or automotive, keyless entry.

MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA
TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB http://www.micrel.com