The Propagation Group

Georgia Institute of Technology

Communication with FCC's Office of Engineering Technology Regarding ISM Compliance of Power-Optimized Waveforms

Document ID: PG-TR-081120-GDD
Date: 11 November 2008

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Executive Summary

This technical report records an exchange of communications between the Georgia Tech Propagation Group and the United States Federal Communication Commission's (FCC) Office of Engineering Technology (OET). The summary describes the operation of a power-optimized waveform (POW) in unlicensed bands, with a focus on how these waveforms comply with federal Part-15 specifications that regulate intentional radiators. The engineering office concludes that the transmission scheme would be allowable in unlicensed industrial-scientific-medical (ISM) bands under the current Part-15 rules. This is the first step for certifying readers that could dramatically increase the read range of passive RFID systems, since the POW transmission waveform may dramatically increase the efficiency of an RF-scavenging device, without increasing the average conducted power of the signal.

Note that this is not a formal certification of RFID readers or any other device that employs POW transmission techniques. However, an informal approval by the FCC OET is a critical first step for certification of such devices.

Reply to an OET Inquiry Response

Currently Display Inquiry Tracking Number: 862188

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Inquiry Details:

First Inquiry Category: **Radio Service Rules**
Second Inquiry Category: **Part 15 Intentional Radiators**
Third Inquiry Category: **Spread Spectrum devices**

At Georgia Tech, we are developing a device that transmits with a novel form of digital modulation in the ISM band. We are proposing an intentional radiator in the 902 ? 928 MHz band that produces a digital waveform with a novel spread-spectrum technique. The application is for a new type of RFID reader, which illuminates a digital signal with a digital waveform that increases the range of various RFID tags. Conventional RFID readers transmit a basic ASK-modulated carrier that conforms to the FCC?s ISM specifications. Our new waveform involves ASK modulation of a synchronized set of subcarriers instead of a single CW carrier. These subcarriers collectively occupy a bandwidth that is greater than the conventional ASK waveform, while remaining within the 902-928 MHz ISM band and conforming to all spectral mask requirements.

Each digital symbol in the proposed waveform now has a rippled envelope, with several peaks and valleys. The overall period and average power of each digital symbol remains unchanged.

Since the average power of each digital symbol is unchanged, the maximum conducted output power is also unchanged and continues to meet the Part 15 specification for an intentional radiator with a digital waveform.

The properties of this signal resemble a spread spectrum and/or OFDM-type digital signal. Are there any unforeseen problems or additional potential restrictions on a waveform of this type operating in the 902-928 MHz band? Would this waveform be allowed by the FCC?

---**Reply from Customer on 10/21/2008**---

Thank you for your reply. I have attached an extended description of the proposed 902-928 MHz digital waveform, intended to work under part 15.247. This document contains several diagrams of spectrum and time-domain waveforms that should clarify the description. Thank you for your time.
---**Reply from Customer on 10/29/2008**---

1. Is the purpose of the modulation on the carrier to solely to expand the bandwidth beyond 500 kHz to meet the rule or is it actually doing more than powering the tag? Explain the information being transmitted with the power.

No. The primary purpose is to shape the digital data that 1) preserves communication functionality, and 2) allows a passive RFID chip to power up more efficiently. A side benefit is that the extra bandwidth would likely make an RFID reader become a more benevolent interferent when compared to narrowband versions.

2. What is this the modulation from the reader or from the tag? How does a Tag work.

The modulation from Reader to RFID tag is a form of ASK. Steps for tag operation are shown below.

3. Could you provide a description of the communication events between the reader and the tag.

Step 1) The RFID powers-up by rectifying the intentional transmitter's waveform. Step 2) The RFID chip then demodulates binary digital ASK signals that communicate commands to the RFID tag. Step 3) When instructed by this init, the UHF RFID tag then reflects its internal identification/data back by modulating its radar cross section.

4. Does it use special or off-the shelf tags?

Initially, we hope to demonstrate this on current off-the-shelf tags. If successful, we would like to specify new RFID chips that are optimized for this transmission scheme.

5. When you look at figure 1 the Digital Symbol 1 is different than Digital Symbol 2. The average over the symbol looks different. Why do you sat the average power of symbol 1 is the same as symbol 2. The unit?s power would be based on the symbol that represents the highest power.

In today's current RFID ASK reader-to-tag communication scheme, the two digital symbols in the alphabet are not the same power. However, our newly proposed signaling scheme would preserve the same average power as the current RFID scheme for each symbol. The graphs in that document are not drawn exactly to scale.

Attached is a PDF explaining more details about how our new waveform works and its designed intent.

---**Reply from Customer on 11/19/2008**---

Here are some answers to your questions. Let me know if you have any further questions.

i. There are two "modes" of this waveform. One is an informationless state that is used to power up the passive RFID tag. The other is a communicative state where the informative ASK waveform is spread with the technique. In this latter case, the technique resembles direct sequence spread spectrum in that it does not add any additional information -- it simply reduces the power spectral density of the waveform. Existing RFID readers have these same two modes of operation. In this case, their power-up waveform is simply a frequency-hopped CW waveform without modulation and their communicative waveform is the same carrier with ASK modulation. The purpose of our "re-shaping" the waveform is to allow the charge pump of a passive RFID circuit to operate more effectively, which will increase its effective range. Currently, passive RFID tags are limited by their ability to rectify an incoming waveform and power-up their internal circuitry with their charge pump/rectifier. Our spread waveform allows this nonlinear charge-pump/rectifier to operate more efficiently for the same average conducted power level of an RFID reader.

ii. For both existing RFID readers and our proposed transmission scheme, each digital symbol would be 20 microseconds (a typical symbol size for one existing RFID standard). Thus, the bit rate would be 50 kbit/s.

iii. In my text, I was comparing symbols between existing RFID reader transmissions and our proposed reader waveform. So "Proposed Symbol 1" has the same time-averaged conducted power as "Conventional Symbol 1" and "Proposed Symbol 2" has the same time-averaged conducted power as "Conventional Symbol 2"; hence, with an alphabet of these 2 digital symbols, the proposed signaling technique has the exact same power as the conventionl/existing RFID reader waveform. It's correct to say that "Symbol 1" does not have the same power as "Symbol 2" in either scheme.

iv. Passive RFID tags return their information by modulating their backscatter -- they are not intentional radiators. They simply change the electrical loading on their antenna, which in turn changes their effective radar cross section (RCS). The RFID tag's binary information is returned to the reader by wobbling the RFID tag's RCS according to another ASK-type modulation. In modern RFID readers, the reader does not turn off during a tag read as this this would starve the RFID tag's circuits from both its operating power as well as the mechanism for communication. Instead, RFID readers rely on their large dynamic range or interference cancellation hardware to recover the weak, backscattered waveform in the presence of their own loud transmission.

Thanks for you time.

-Greg

Response(s):

--OET response sent on Oct 15 2008 5:50PM--

First, as with any system you need to target a specific rule part. Based on your description this appears to be digital modulation under 15.247. This permits operation in the 902-928 MHz band and the minimum bandwidth must be at least 500 KHz. The maximum output power is expressed in peak conducted limits or maximum conducted output power. However, we would need more detail on what is meant by overall period and average power of each digital symbol. You should review 15.247 and then provide more detail information for a specific answer.

--OET response sent on Oct 28 2008 12:03PM--
Please provide additional information about this system:

i. Is the purpose of the modulation on the carrier to solely to expand the bandwidth beyond 500 kHz to meet the rule or is it actually doing more than powering the tag? Explain the information being transmitted with the power.
ii. What is this the modulation from the reader or from the tag? How does a Tag work.

iii. Could you provide a description of the communication events between the reader and the tag.
iv. Does it use special or off-the shelf tags?
v. When you look at figure 1 the Digital Symbol 1 is different than Digital Symbol 2. The average over the symbol looks different. Why do you sat the average power of symbol 1 is the same as symbol 2. The unit?s power would be based on the symbol that represents the highest power.

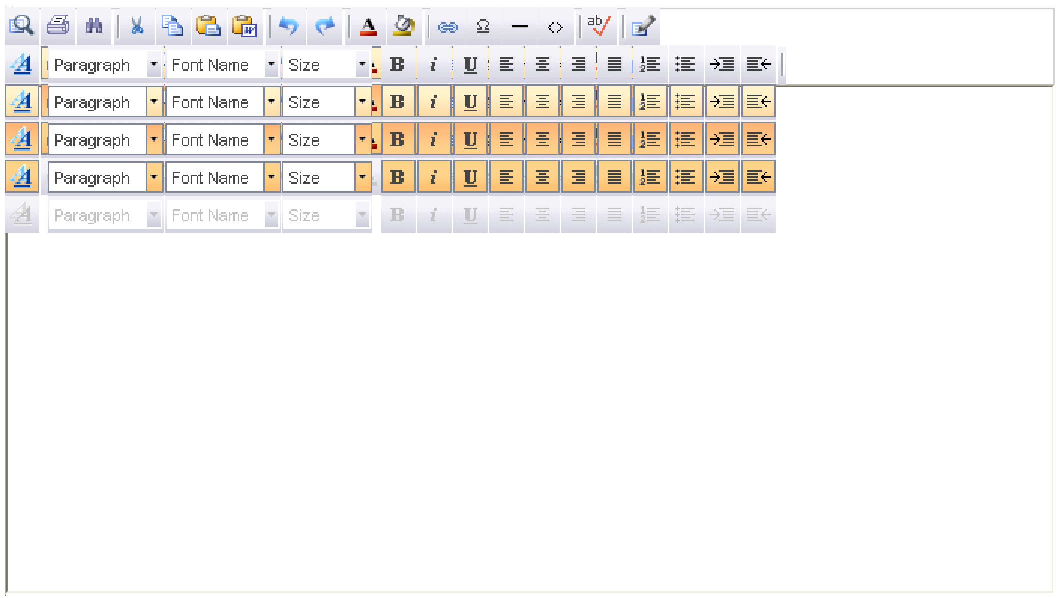
--OET response sent on Nov 19 2008 8:29AM--
Sorry, for the late response. There are still of a few questions that we need to understand.

i. Based on your description, there does not seem to be any information encoded in the spreading process. Unlike Spread spectrum were the information is multiplied by spreading signal and de-spread to recover the information, it appears that you are only spreading the signal to power the remote Tag. You mention that this is more efficient. Could you explain this?
ii. The information appears to be transmitted by two levels representing binary symbols. What is the rate? Please provide the information rate.
iii. You also mention that the power is the same for each symbol. But if ASK is being used explain how it is the same.
iv. Also, how is the Tag return information being received? I assume that you turn off the transmitter to listen for a response. What is the protocol?

The information being requested is to determine if the system could also work without the Spreading carrier and that the only reason for the spreading is to comply with the 15.247 digital transmission rules.

--OET response sent on Nov 20 2008 2:18PM--
Greg, this waveform would be allowed by the FCC under 15.247. It would have to meet all of the conditions that it meets all requirements for a Digital Transmission System and all applicable rule parts..

Enter any additional comments below:



Proceed Clear

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Proposed Part 15.247 Digital Waveform for the 915 MHz ISM Band

by Gregory D. Durgin and Matthew S. Trotter

We would like to confirm the compliance of a new ISM intentional radiator that operates under the Part 15.247 rules for digital transmission. The following text describes the nature of the transmitted waveform, demonstrating how we believe the transmitted signal would comply with the current FCC requirements.

At Georgia Tech, we are developing a device that transmits with a novel form of digital modulation in the ISM band. We are proposing an intentional radiator in the 902 – 928 MHz band that produces a digital waveform with a novel spread-spectrum technique. The application is for a new type of RFID reader, which illuminates a digital signal with a digital waveform that increases the range of various RFID tags. Conventional RFID readers transmit a basic ASK-modulated carrier that conforms to the FCC's ISM specifications. Our new waveform involves ASK modulation of a synchronized set of subcarriers instead of a single CW carrier. These subcarriers collectively occupy a bandwidth that is greater than the conventional ASK waveform, while remaining within the 902-928 MHz ISM band and conforming to all spectral mask requirements.

Each digital symbol in the proposed waveform now has a rippled envelope, with several peaks and valleys. The overall period and conducted power of each digital symbol remains unchanged. Since the average power of each digital symbol is unchanged, the maximum conducted output power is also unchanged according to the definition in Part 15.247.

Figure 1 illustrates the difference between conventional ASK radiated symbols and the new proposed ASK radiated symbols in the time domain. The symbol period of approximately 2μs is identical for both proposed waveforms; only the symbol shape is changed in the proposed digital waveform.

Figure 2 illustrates the difference between a conventional digital waveform and the new proposed radiated spectrum in the frequency domain. In fact, the properties of this new, proposed signal resemble a spread spectrum and/or OFDM-type digital signal, occupying more bandwidth at a lower power-spectral density than a conventional digital waveform. The waveform may occupy anywhere from 1 to 8 MHz of total bandwidth, depending on the chosen time-domain shape of the waveform. According to the Part 15.247 rules, the spectral mask must not exceed "8 dBm in any 3 kHz band during any interval of transmission". Since the conventional ASK waveform does not exceed this maximum power spectral density requirement, the proposed spread-spectrum version of this waveform will be significantly less than this transmitted power density maximum.

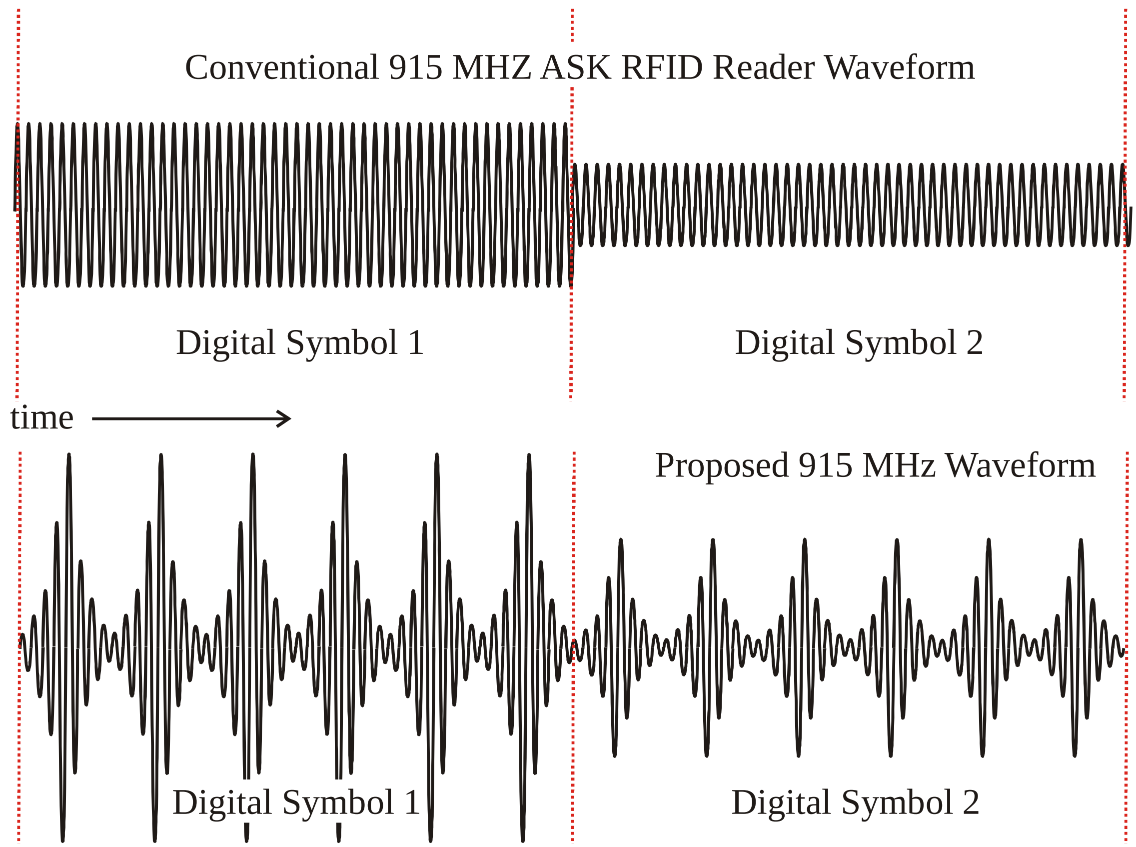

Figure 1: Time domain sketch of conventional 915 MHz ASK digital symbols and the proposed waveform digital symbols, both of which maintain identical levels of maximum conducted output power.

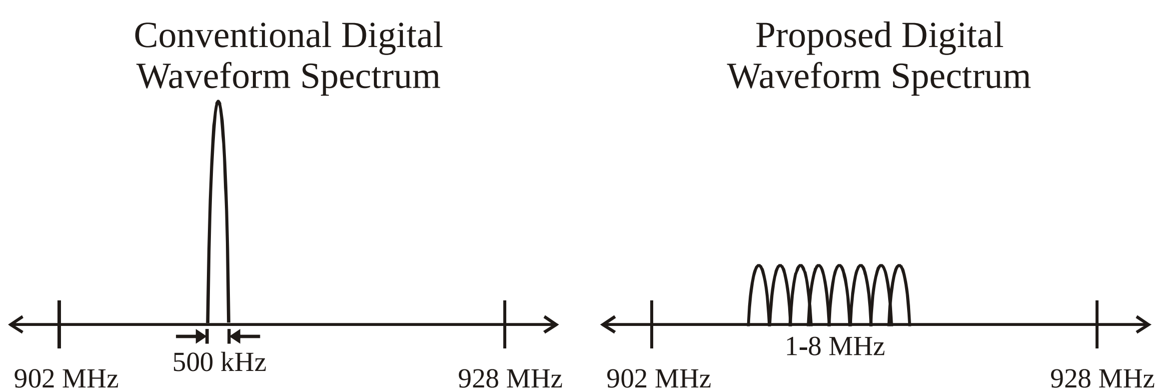

Figure 2: Sketch of the spectrum of conventional digital (left) and proposed digital (right) signals, both of which maintain identical levels of maximum conducted output power.