RADIO MAGiC

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ISM Band "HiFER" Beacons: Part 1

Introduction

The industrial, scientific and medical (ISM) radio frequency (RF) bands are very low radiated power, licence-exempt segments of the electromagnetic (EM) spectrum allocated in 1947 by the International Telecommunication Union (ITU). At first, it was only intended for these three specific fields (as the primary users) because the equipment used is esoteric to them: i.e. high-energy particle colliders, magnetic resonance imagers (MRIs), X-ray machines, industrial microwave ovens, etc. These devices can unintentionally radiate very strong EM fields generating very strong EM interference (EMI) disrupting other electric/electronic devices, or even worse, irradiate people whom they shouldn't so they must meet strict safety standards.

Eventually, the ISM bands where forced to expand beyond their original intent because commercial and consumer low-power, licence-exempt devices demanded more and more RF room, as the secondary users (they must not interfere with primary users). The began to eat slowly away at the limited space available because the various ISM bands are surrounded by other international radio services: Amateur, Citizen's Band (CB), Family Radio Service (FRS), maritime, aviation, weather, satellite, etc. A few of today's ISM band secondary uses are listed in Figure 1 (next page). While the ISM frequencies range from high to super high (HF to SHF) frequencies (see Table 1, next page), my main focus is on the 22 metre (m) HF experimental radio (HiFER) segment.

Figure 1: Typical ISM Band Applications

When you tap 'n go your debit/credit card it communicates with a radio frequency identification (RFID) reader using an ISM frequency. Credit: SlideShare, P. Farell.

Frequency range		Center frequency	Bandwidth	Availability	Licensed users
6.765 MHz	6.795 MHz	6.78 MHz	30 kHz	Subject to local acceptance	FIXED SERVICE & Mobile service (42 m HiFER)
13.553 MHz	13.567 MHz	13.56 MHz	14 kHz	Worldwide	FIXED & Mobile services except Aeronautical mobile (R) service (22 m HiFER)
26.957 MHz	27.283 MHz	27.12 MHz	326 kHz	Worldwide	FIXED & MOBILE SERVICE except Aeronautical mobile service, CB Radio
40.66 MHz	40.7 MHz	40.68 MHz	40 kHz	Worldwide	Fixed, Mobile services & Earth exploration-satellite service
433.05 MHz	434.79 MHz	433.92 MHz	1.74 MHz	only in Region 1, subject to local acceptance	AMATEUR SERVICE & RADIOLOCATION SERVICE (Not designated for ISM use in U.S.)
902 MHz	928 MHz	915 MHz	26 MHz	Region 2 only (with some exceptions)	FIXED, Mobile except aeronautical mobile & Radiolocation service; in Region 2 additional Amateur service
2.4 GHz	2.5 GHz	2.45 GHz	100 MHz	Worldwide	FIXED, MOBILE, RADIOLOCATION, Amateur & Amateur-satellite service
5.725 GHz	5.875 GHz	5.8 GHz	150 MHz	Worldwide	FIXED-SATELLITE, RADIOLOCATION, MOBILE, Amateur & Amateur-satellite service
24 GHz	24.25 GHz	24.125 GHz	250 MHz	Worldwide	AMATEUR, AMATEUR-SATELLITE, RADIOLOCATION & Earth exploration-satellite service (active)
61 GHz	61.5 GHz	61.25 GHz	500 MHz	Subject to local acceptance	FIXED, INTER-SATELLITE, MOBILE & RADIOLOCATION SERVICE
122 GHz	123 GHz	122.5 GHz	1 GHz	Subject to local acceptance	EARTH EXPLORATION-SATELLITE (passive), FIXED, INTER-SATELLITE, MOBILE, SPACE RESEARCH (passive) & Amateur service
244 GHz	246 GHz	245 GHz	2 GHz	Subject to local acceptance	RADIOLOCATION, RADIO ASTRONOMY, Amateur & Amateur-satellite service

Table 1: ISM Band Frequencies

Credit: Spectrum Management and Telecommunications.

HiFER Beacon Regulations

The Canadian Radio Standards Specifications (RSS)-210 Licence-Exempt Radio Apparatus: Category I Equipment and the U.S. Code of Federal Regulations (CFR), Title 47, Part 15 publications are very similar. No federal licence is required to operate within the ISM bands, but hobbyists are secondary users so there're some very strict regulations regarding radiated field strengths and antenna restrictions plus consumer manufactured and sold devices must be certified and operated by the authority of the applicable Canadian RSS, and must have a sticker or plate affixed to the outside of their housings stating this fact. The equivalent U.S. Part 15 type acceptance is valid in Canada and vice versa.

Talking specifically about the 22 m ISM band regulations, wherein we can *only radiate a field strength (FS) reading of not more than 15,848 microvolts per metre (µV/m) at 30 m from an RF radiator in the 13.553 to 13.567 MHz range by an antenna with no more gain than that of a dipole.* However, Amateurs don't measure the FS readings at 30 m surrounding their RF radiators (antennas), fortunately, John Andrews, W1TAG, worked out the complex conversion mathematics to determine the equivalent RF power: for a dipole antenna it's a *maximum* of 4.6 milliwatts (mW) and for a quarter-wave vertical antenna it's 2.3 mW. For those without QRPp wattmeters, he also converted these values for RF voltmeter and oscilloscope use, respectively: 4.6 mW is 0.48 volts Root Mean Square (V_{RMS}) or 1.36 V peak-to-peak (V_{P-P}) and 2.3 mW is 0.34 V_{RMS} or 0.96 V_{P-P}.

The regulations also state that *the carrier frequency stability shall not exceed 100 ppm (parts-per-million).* In this case, the maximum allowable frequency error is about 136 hertz (Hz).

And per the ITU World Radio Conference (WRC) regulations (WRC-03, Appendix 3): *The minimum (second) harmonic attenuation required for low-power (< 100 mW), licence-exempt device radio equipment is $56 + 10\log_{10}(P)$, or 40 dBc, whichever is less stringent.* Where "dBc" is decibels relative to the carrier and "P" is the mean power in watts (W) *applied to the input of the antenna transmission line*.

Example (using 4.6 mW): $56 + 10\log_{10}(.0046) = 56 + (-23.37)$ or 32.63 dBc.

In this specific case, 32.63 dBc is less stringent than 40 dBc, but the tried and true Pi low pass filter (LPF) or even the second tried and true half-wave LPF design can't provide the less stringent level of harmonic attenuation so we need to use different types of LPF designs. Now, you may laugh at "flea" power transmitters having such stringent restrictions, but a radio inspector once told me that EMI issues are sometimes determined to be caused by devices unintentionally radiating as little as 90 nanowatts (nW) of stray harmonics into the local ether!

On the plus side, you can operate unattended (no control operator present) 22 m HiFER beacons 24/7; you can experiment with various data encryption/decryption techniques, which is a definite "no-no" on the Amateur Radio bands, plus you don't need to use a "proper" call sign but most Amateurs usually use their suffixes ("ROM", in my case). The 22 m ISM band is very popular because it's authorized for world-wide use, there's a plethora of inexpensive ISM 13.56 MHz crystals available, anyone can build and use HiFER transmitters sans licence, provided they comply with the regulations, plus the band has similar propagation characteristics of the nearby Amateur Radio 20 m band so even a flea power HiFER beacon signal can jump a long way with decent propagation conditions.

Note: While the 42 m ISM band (6.765 to 6.795 MHz) is authorized for use in Canada, the maximum allowable radiated FS is only 106 µV/m at 30m; using W1TAG's equations, that's 205 nW (dipole) and 102.5 nW (vertical)—a "tick" power transmitter!

HiFER Beacon Designs and Uses

The inspiration for this project came from Stephen Page, VK6HV's PICAXE-08M micro controller (µ-controller) Amateur Radio 10 m band continuous wave Morse code (CW) propagation beacon using a crystal oscillator transmitter (see Figure 2, next page) and the Black Cat Systems Par15 kit. Black Cat's HiFER transmitter uses a crystal controlled integrated circuit (IC) logic chip transmitter and an ATTiny85 µ-controller (see Figure 3, next page). HiFER beacons are used primarily for propagation purposes and programmed to transmit, at specific intervals, a call sign (or other station identification) and perhaps their Maidenhead grid square locator (but not always).

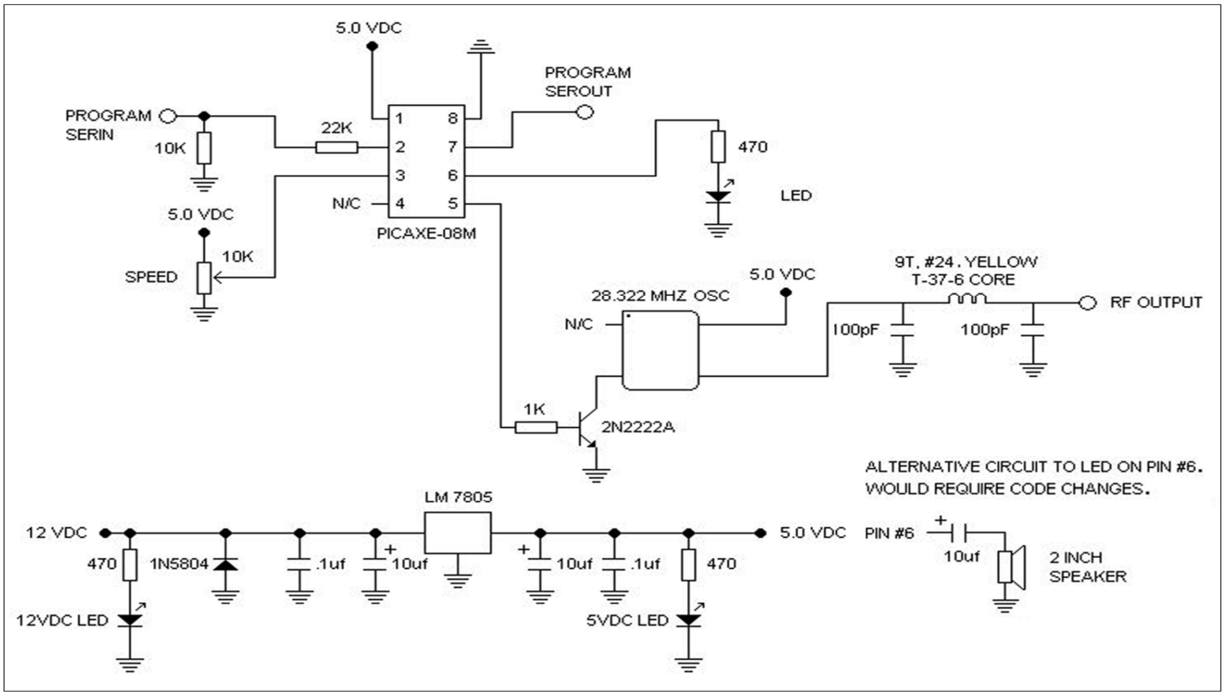

Figure 2: PICAXE-08M 10 m CW Beacon

Not a true HiFER beacon because it's used on the 10 m Amateur Radio band. The Pi filter doesn't meet today's harmonic attenuation requirements. Credit: Stephen Page, VK6HV.

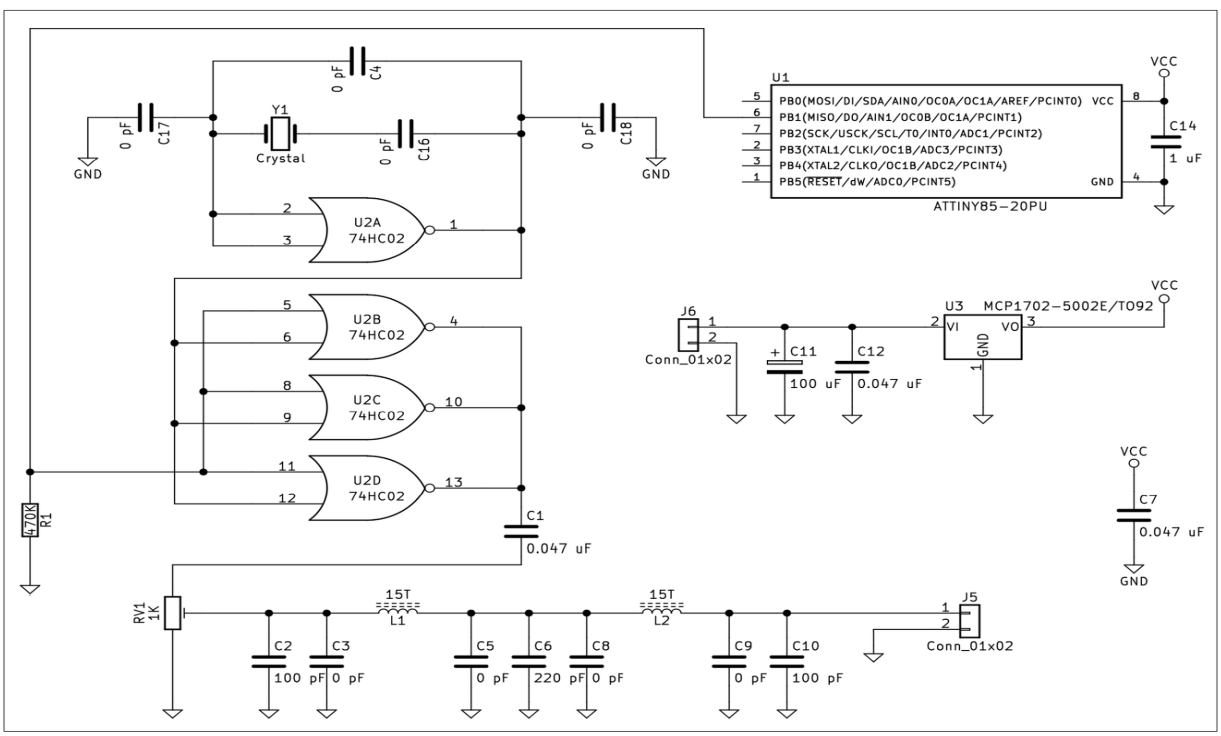

Figure 3: Quad-NOR Gate IC ATtiny85 22 m HiFER Beacon

The half-wave LPF doesn't meet today's harmonic attenuation standards, but add a 39 pF capacitor across L2 and it does! Credit: Black Cat Systems.

Thinking a bit outside the box, a HiFER transmitter can be connected to a solar panel/rechargeable battery combo, put inside a weatherproof housing and located at some remote location. Sensors added to the µ-controller can monitor whatever you want and transmit telemetry (data) to a distant receiver. Or everything can be located in the same room for classroom/public demonstrations and/or testing purposes. The later is a really good thing to do *before* dropping your beacon off in the boonies or flying it away on an Amateur Radio high altitude balloon (ARHAB)!

So here's the engineering problem: my JAYCO trailer is located at a year-round access campsite in a deep valley located 10 kilometres (km) as the crow flies from the City of Thunder Bay (25 km by road). Cell phone use requires an outside antenna to hit the nearest tower; there's no electricity, landlines or Wi-Fi. Basically, you bring in everything needed to "rough it", but it's a conveniently close to town campsite with a "rural quiet" or very low radio noise floor, which is great for weak-signal data modes reception. So I would like to monitor the solar panel/trailer battery voltage levels and site environment: temperature, dew point, humidity, pressure and light level (it's the former weather observer in me).

Note: The OPEN-SMART Rich Shield Arduino shield (my TCA Jul-Aug 2020 article refers) provides nearly all the sensors used for this project (see Figure 4, next page).

Because of the close-in distance between transmitter and receiver sites, it's perfect for experimenting with "near-incident vertical skywave" (NVIS) propagation, but I'm too way too high in frequency because NVIS only really works on the low bands (usually 80 m is optimum), and I suspect that the 22 m signal will just skip over Thunder Bay and land somewhere else hundreds or even thousands of km away. But if that's the case, I can use one of the many public access software defined radio (SDR) receiver websites for remote monitoring of a local radio signal! Experimentation is the only way to answer my questions and point out any flaws in what I want to do and what I can do.

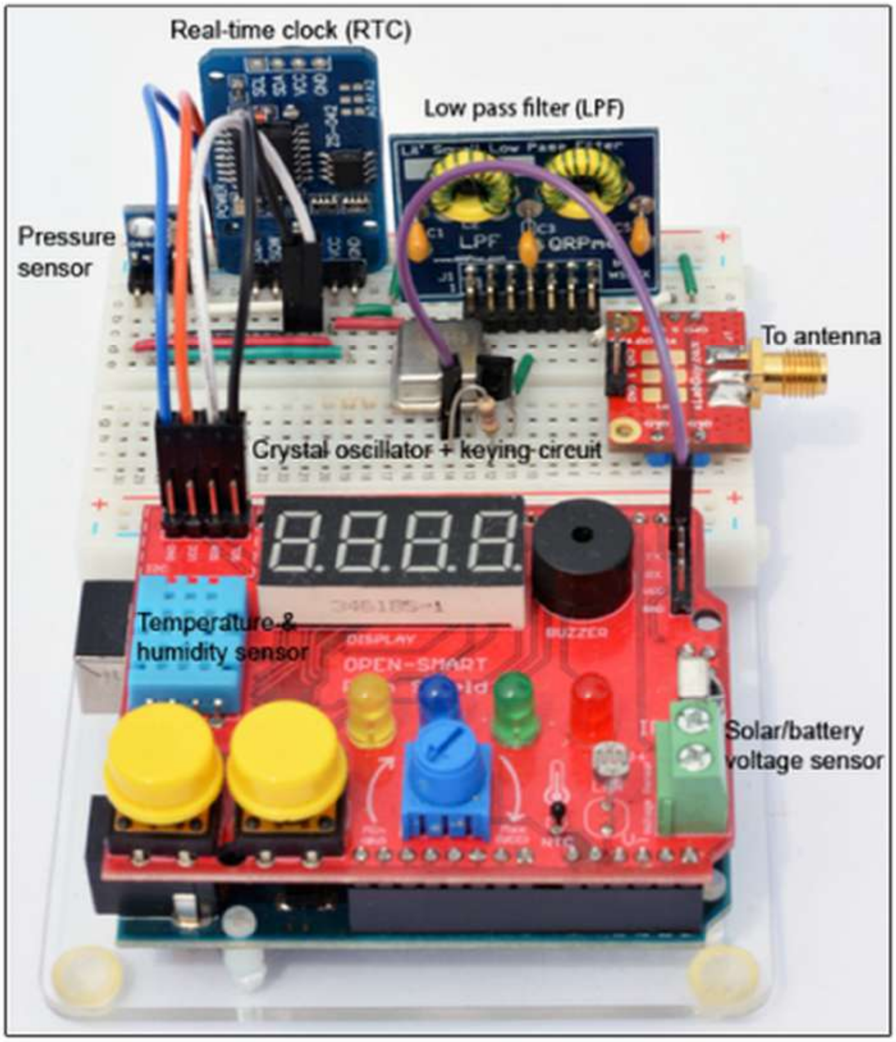

Figure 4: HiFER Uno Beacon
My telemetry transmitter: part propagation beacon, part weather and solar/battery power sensors monitoring. It works great in the shack but what about when operating the "wild"? It's frequency agile and can be used on the Amateur Radio bands.

My Final

Experimenting with µ-controllers, coding, telemetry, transmitters, receivers, filters, antennas, propagation or even creating abstract "etheric" art ala Canadian interdisciplinary artist Amanda Dawn Christie (http://www.amandadawnchristie.ca) is a great way to introduce the young "Makers" of today and tomorrow to the "magical" world of radio! Part 2 continues on with my foray into the HiFER world. By then, hopefully, I'll have a few months of real-world operating experience and can write more about how well everything is working or isn't.—73