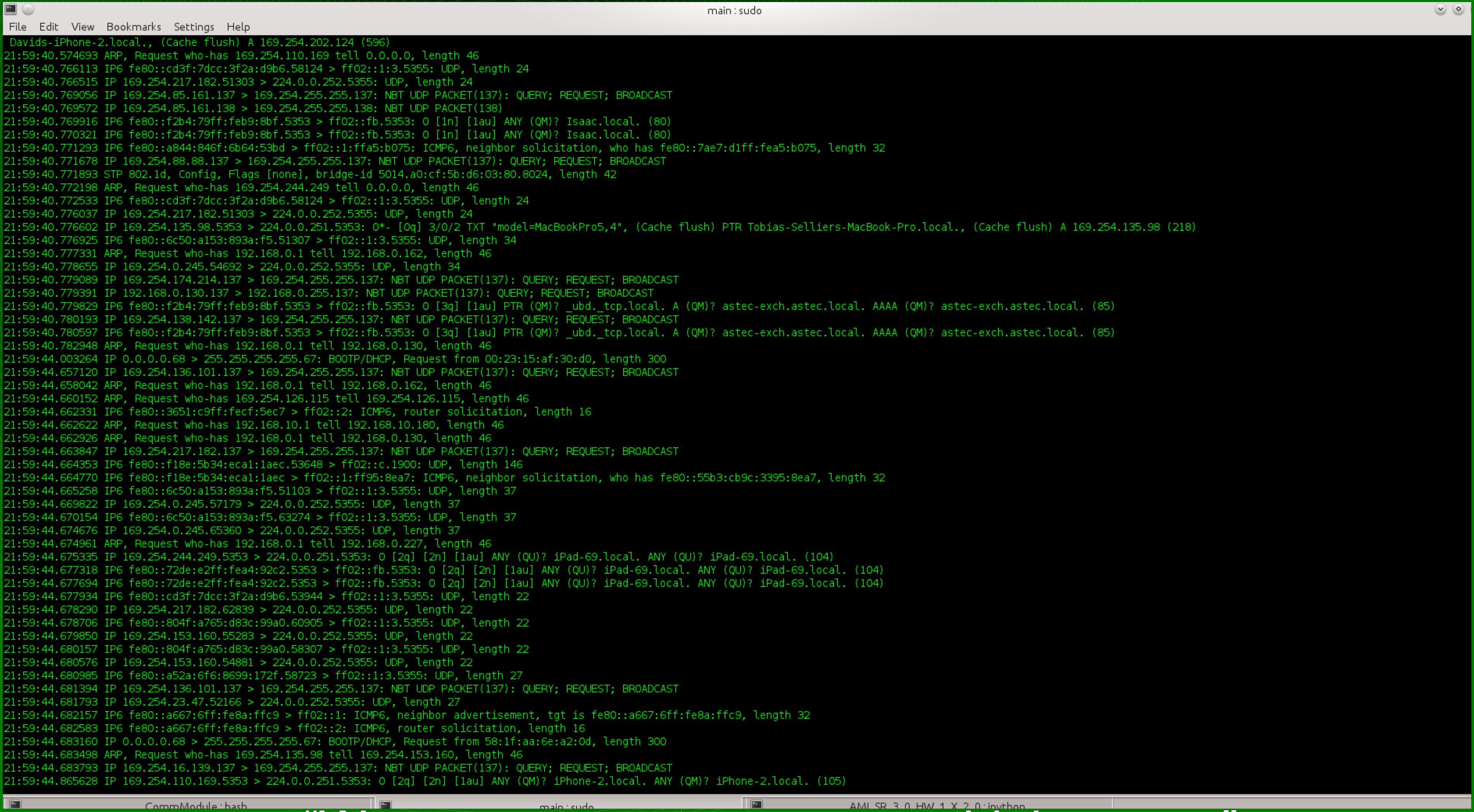
0x0000


main : sudo
File Edit View Bookmarks Settings Help
CommModule : bash
main : sudo
AML SR 3.0 HW 1 X 2.0 : ipython

```
 Davids-iPhone-2.local., (Cache flush) A 169.254.202.124 (596)
21:59:40.574693 ARP, Request who-has 169.254.110.169 tell 0.0.0.0, length 46
21:59:40.766113 IP6 fe80::cd3f:7dcc:3f2a:d9b6.58124 > ff02::1:3.5355: UDP, length 24
21:59:40.766515 IP 169.254.217.182.51303 > 224.0.0.252.5355: UDP, length 24
21:59:40.769056 IP 169.254.85.161.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:40.769572 IP 169.254.85.161.138 > 169.254.255.255.138: NBT UDP PACKET(138)
21:59:40.769916 IP6 fe80::f2b4:79ff:feb9:8bf.5353 > ff02::fb.5353: 0 [1n] [1au] ANY (QM)? Isaac.local. (80)
21:59:40.770321 IP6 fe80::f2b4:79ff:feb9:8bf.5353 > ff02::fb.5353: 0 [1n] [1au] ANY (QM)? Isaac.local. (80)
21:59:40.771293 IP6 fe80::a844:846f:6b64:53bd > ff02::1:ffa5:b075: ICMP6, neighbor solicitation, who has fe80::7ae7:d1ff:fea5:b075, length 32
21:59:40.771678 IP 169.254.88.88.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:40.771893 STP 802.1d, Config, Flags [none], bridge-id 5014.a0:cf:5b:d6:03:80.8024, length 42
21:59:40.772198 ARP, Request who-has 169.254.244.249 tell 0.0.0.0, length 46
21:59:40.772533 IP6 fe80::cd3f:7dcc:3f2a:d9b6.58124 > ff02::1:3.5355: UDP, length 24
21:59:40.776037 IP 169.254.217.182.51303 > 224.0.0.252.5355: UDP, length 24
21:59:40.776602 IP 169.254.135.98.5353 > 224.0.0.251.5353: 0*- [0q] 3/0/2 TXT "model=MacBookPro5,4", (Cache flush) PTR Tobias-Selliers-MacBook-Pro.local., (Cache flush) A 169.254.135.98 (218)
21:59:40.776925 IP6 fe80::6c50:a153:893a:f5.51307 > ff02::1:3.5355: UDP, length 34
21:59:40.777331 ARP, Request who-has 192.168.0.1 tell 192.168.0.162, length 46
21:59:40.778655 IP 169.254.0.245.54692 > 224.0.0.252.5355: UDP, length 34
21:59:40.779089 IP 169.254.174.214.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:40.779391 IP 192.168.0.130.137 > 192.168.0.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:40.779829 IP6 fe80::f2b4:79ff:feb9:8bf.5353 > ff02::fb.5353: 0 [3q] [1au] PTR (QM)? _ubd._tcp.local. A (QM)? astec-exch.astec.local. AAAA (QM)? astec-exch.astec.local. (85)
21:59:40.780193 IP 169.254.138.142.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:40.780597 IP6 fe80::f2b4:79ff:feb9:8bf.5353 > ff02::fb.5353: 0 [3q] [1au] PTR (QM)? _ubd._tcp.local. A (QM)? astec-exch.astec.local. AAAA (QM)? astec-exch.astec.local. (85)
21:59:40.782948 ARP, Request who-has 192.168.0.1 tell 192.168.0.130, length 46
21:59:44.003264 IP 0.0.0.0.68 > 255.255.255.255.67: BOOTP/DHCP, Request from 00:23:15:af:30:d0, length 300
21:59:44.657120 IP 169.254.136.101.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:44.658042 ARP, Request who-has 192.168.0.1 tell 192.168.0.162, length 46
21:59:44.660152 ARP, Request who-has 169.254.126.115 tell 169.254.126.115, length 46
21:59:44.662331 IP6 fe80::3651:c9ff:fecf:5ec7 > ff02::2: ICMP6, router solicitation, length 16
21:59:44.662622 ARP, Request who-has 192.168.10.1 tell 192.168.10.180, length 46
21:59:44.662926 ARP, Request who-has 192.168.0.1 tell 192.168.0.130, length 46
21:59:44.663847 IP 169.254.217.182.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:44.664353 IP6 fe80::f18e:5b34:eca1:1aec.53648 > ff02::c.1900: UDP, length 146
21:59:44.664770 IP6 fe80::f18e:5b34:eca1:1aec > ff02::1:ff95:8ea7: ICMP6, neighbor solicitation, who has fe80::55b3:cb9c:3395:8ea7, length 32
21:59:44.665258 IP6 fe80::6c50:a153:893a:f5.51103 > ff02::1:3.5355: UDP, length 37
21:59:44.669822 IP 169.254.0.245.57179 > 224.0.0.252.5355: UDP, length 37
21:59:44.670154 IP6 fe80::6c50:a153:893a:f5.63274 > ff02::1:3.5355: UDP, length 37
21:59:44.674676 IP 169.254.0.245.65360 > 224.0.0.252.5355: UDP, length 37
21:59:44.674961 ARP, Request who-has 192.168.0.1 tell 192.168.0.227, length 46
21:59:44.675335 IP 169.254.244.249.5353 > 224.0.0.251.5353: 0 [2q] [2n] [1au] ANY (QU)? iPad-69.local. ANY (QU)? iPad-69.local. (104)
21:59:44.677318 IP6 fe80::72de:e2ff:fea4:92c2.5353 > ff02::fb.5353: 0 [2q] [2n] [1au] ANY (QU)? iPad-69.local. ANY (QU)? iPad-69.local. (104)
21:59:44.677694 IP6 fe80::72de:e2ff:fea4:92c2.5353 > ff02::fb.5353: 0 [2q] [2n] [1au] ANY (QU)? iPad-69.local. ANY (QU)? iPad-69.local. (104)
21:59:44.677934 IP6 fe80::cd3f:7dcc:3f2a:d9b6.53944 > ff02::1:3.5355: UDP, length 22
21:59:44.678290 IP 169.254.217.182.62839 > 224.0.0.252.5355: UDP, length 22
21:59:44.678706 IP6 fe80::804f:a765:d83c:99a0.60905 > ff02::1:3.5355: UDP, length 22
21:59:44.679850 IP 169.254.153.160.55283 > 224.0.0.252.5355: UDP, length 22
21:59:44.680157 IP6 fe80::804f:a765:d83c:99a0.58307 > ff02::1:3.5355: UDP, length 22
21:59:44.680576 IP 169.254.153.160.54881 > 224.0.0.252.5355: UDP, length 22
21:59:44.680985 IP6 fe80::a52a:6f6:8699:172f.58723 > ff02::1:3.5355: UDP, length 27
21:59:44.681394 IP 169.254.136.101.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:44.681793 IP 169.254.23.47.52166 > 224.0.0.252.5355: UDP, length 27
21:59:44.682157 IP6 fe80::a667:6ff:fe8a:ffc9 > ff02::1: ICMP6, neighbor advertisement, tgt is fe80::a667:6ff:fe8a:ffc9, length 32
21:59:44.682583 IP6 fe80::a667:6ff:fe8a:ffc9 > ff02::2: ICMP6, router solicitation, length 16
21:59:44.683160 IP 0.0.0.0.68 > 255.255.255.255.67: BOOTP/DHCP, Request from 58:1f:aa:6e:a2:0d, length 300
21:59:44.683498 ARP, Request who-has 169.254.135.98 tell 169.254.153.160, length 46
21:59:44.683793 IP 169.254.16.139.137 > 169.254.255.255.137: NBT UDP PACKET(137): QUERY; REQUEST; BROADCAST
21:59:44.865628 IP 169.254.110.169.5353 > 224.0.0.251.5353: 0 [2q] [2n] [1au] ANY (QM)? iPhone-2.local. ANY (QM)? iPhone-2.local. (105)
```

"We are not as strong as we think we are"

- Rich Mullins

<GHz or bust!

leveraging the power of the chipcon 1111
and RfCat

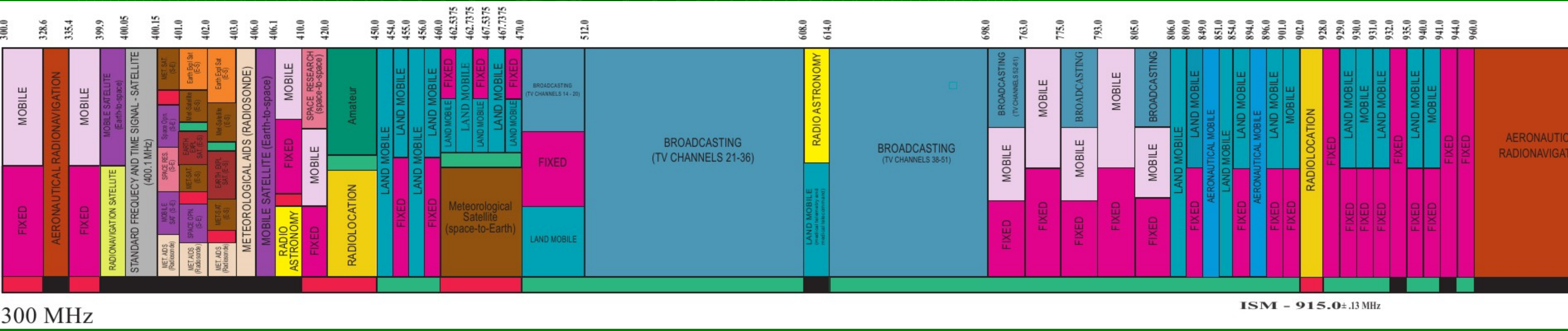
0a71a5@gmail.com

0x0001 – workshop plan - ejercicios

- lessons to teach:
  - play around with modulation/baud/etc...
  - using the dongle to tune in and listen
  - using the dongle to determine, and transmit
  - playing with the dongle... it's just fun!
- toys to play with:
  - Garage door opener
  - Keyless entry fob
  - Power Meter
  - Glucometer
  - IMME 1

0x0002 – installing the client

- once you have a cc1111 dongle flashed with RfCat...
- install client according to the README
- blackhat release:
  - https://rfcat.googlecode.com/files/rfcat-blackhat2012.tgz
  - https://rfcat.googlecode.com/files/RfCatChronos.hex
  - https://rfcat.googlecode.com/files/RfCatDons.hex



0x1000 – intro to <GHz and unlicensed ISM

- ITU-R 5.138, 5.150, and 5.280 rules
- US FCC Rules(title 47) parts 15 and 18
  - Industrial – power grid stuff and more!
  - Science – microwave ovens?
  - Medical – insulin pumps and the like
- Popular ISM bands (vary around the world)`:
  - 300 : 300 – 330 MHz
  - 433 : 433.050 – 434.790 MHz
  - 868 : 863.000 – 870.000 MHz
  - 915 : 902.000 – 928.000 MHz
  - cc1111 does 300-348, 372-460, 779-928... but much more.
- Other ISM includes 2.4 GHz and 5.8 GHz
  - cc2531.... hmmm... maybe another toy?

0x1010 – what plays <GHz?

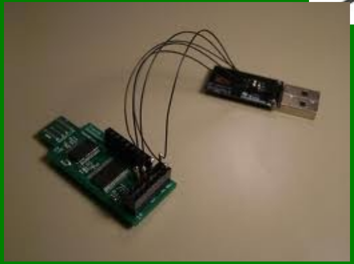
- Industry, Science, Medical bands, US and EU
- Cell phones
- Cordless Phones
- Personal Two-Way Radios
- Car Remotes
- Pink IM-ME Girl Toys!
- TI Chronos Watches
- Medical Devices (particularly 401-402MHz, 402-405MHz, 405-406MHz)
- Power Meters
- custom-made devices
- Old TV Broadcast
- much, much more...

0x1020 – how do we play with it?

- cc1110/cc1111 do 300-348MHz, 391-464MHz, 782-928MHz
  - and more...
- RFCAT uses the CC111x on some common dongles

  - Chronos dongle (sold with every TI Chonos watch)
  - “Don's Dongles”, aka TI CC1111EMK
  - IMME (currently limited to sniffer/detection firmware)

- ahh, but there are some catches
  - rf comms configuration?
  - channel hopping sequence/sync?
  - bluetooth and DSSS? (not hap'nin)



0x1030 – why do i care!?

- the inner rf geek in all of us
- your security research may require that you consider comms with a wireless device
- your organization may **have** 900MHz devices that should be protected!
    - anyone heard of telxon!?
    - how about P25?
    - power companies... pay attention.

0xEC – extra credit... know now.

- IMME currently set up in the room
- it transmits a packet “BLACKHAT RULEZ!!” every ~10secs
- using what you learn in this workshop, identify where in the spectrum it is (what frequency) and other RF configuration items
- and transmit your own message
  - it will be displayed on the IMME's screen
- “So cool and connected!”

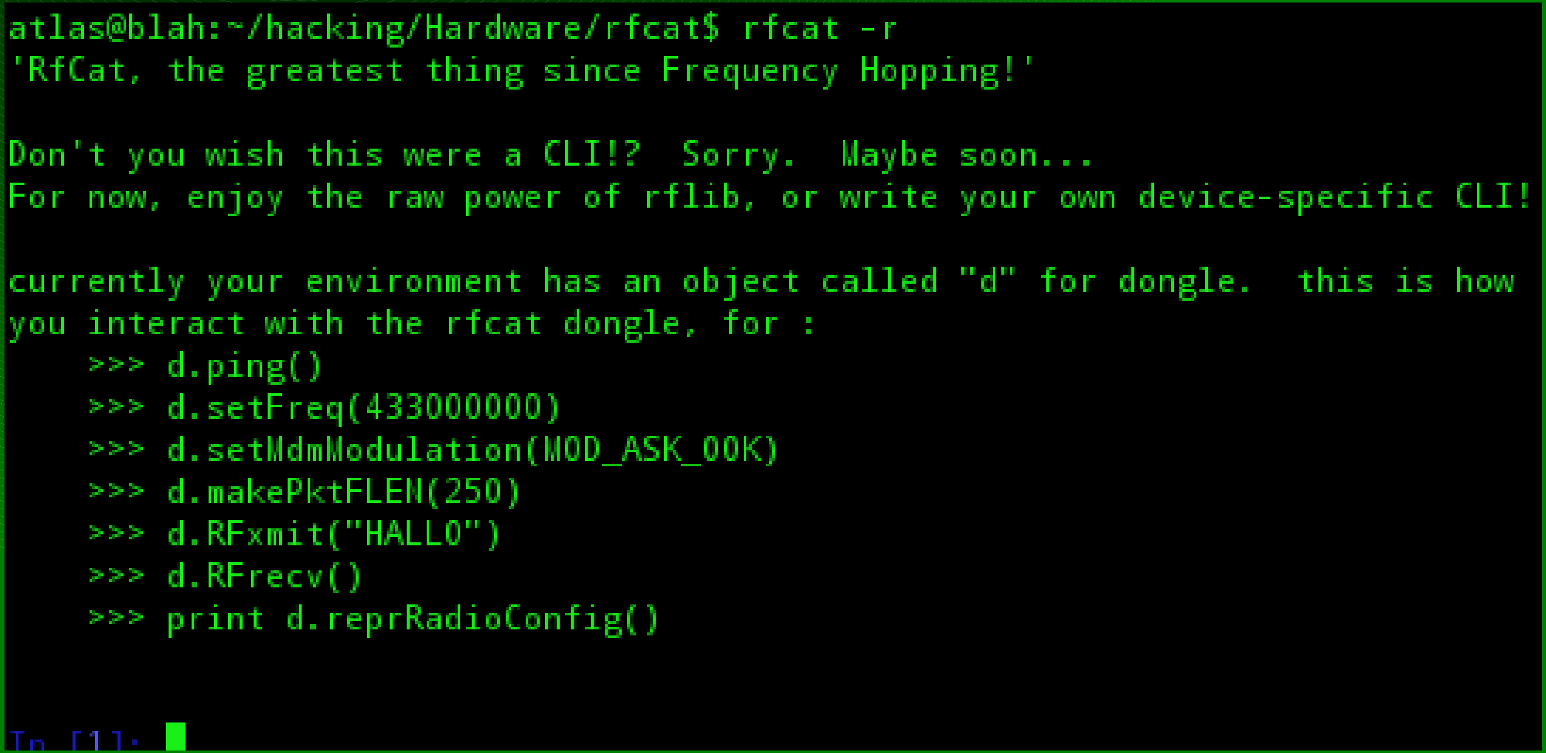
0xE1 – workshop ej 1 – getting started

$ tar zxf rfcat-blackhat2012.tgz

$ cd rfcat-blackhat2012

$ sudo python setup.py install (trust me!)

$ sudo rfcat -r (follow instructions in README to avoid sudo)



```
atlas@blah:~/hacking/Hardware/rfcat$ rfcat -r
'RfCat, the greatest thing since Frequency Hopping!'

Don't you wish this were a CLI!?  Sorry.  Maybe soon...
For now, enjoy the raw power of rflib, or write your own device-specific CLI!

currently your environment has an object called "d" for dongle.  this is how
you interact with the rfcat dongle, for :
    >>> d.ping()
    >>> d.setFreq(433000000)
    >>> d.setMdmModulation(MOD_ASK_OOK)
    >>> d.makePktFLEN(250)
    >>> d.RFxmit("HALLO")
    >>> d.RFrecv()
    >>> print d.reprRadioConfig()


In [1]: 
```

0xE2 – workshop ej 2 – listen to teacher

```
$ rfcat -r
>>> d.setMdmModulation(MOD_ASK_OOK)
>>> d.setMaxPower()
>>> d.setMdmDRate(9600)
>>> d.makePktVLEN()                    # variable length packet
>>> d.RFlisten()
```

0x2000 - intro to the cc1111 core

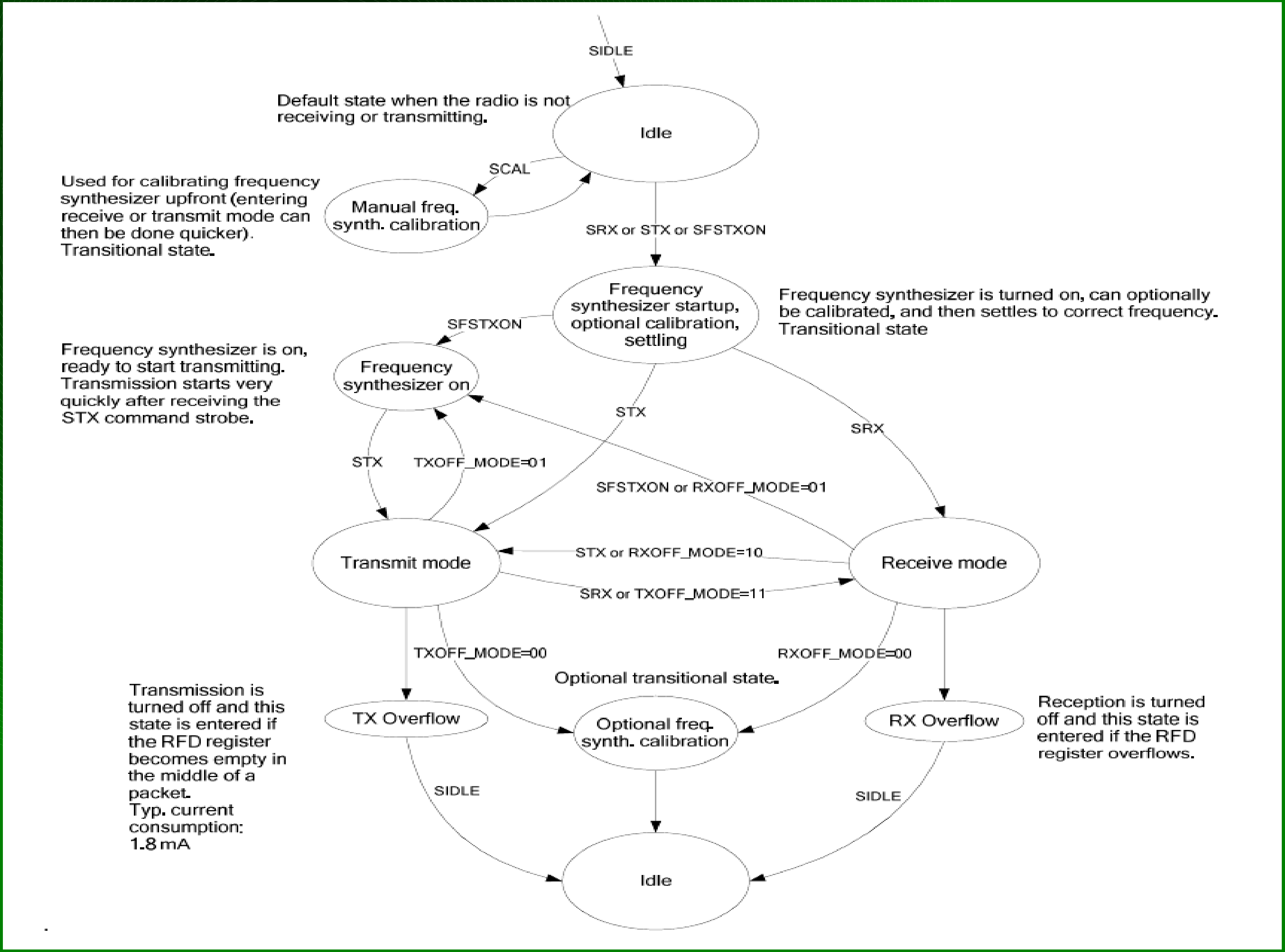
- for the devs in the house...
  - mcu
  - radio state engine
  - radio configuration
  - usb
  - timers
  - dma

0x2010 – cc1111 mcu

- modified 8051 core
  - 8-bit mcu
  - single-tick instructions
  - 256 bytes of iram
  - 4kb of xram
  - XDATA includes all code, iram, xram
  - execution happens anywhere :)
- register access to radio, dma, crypto, usb, timers, adc
- registers are simply memory locations is the XDATA address space

0x2020 – cc1111 radio state engine

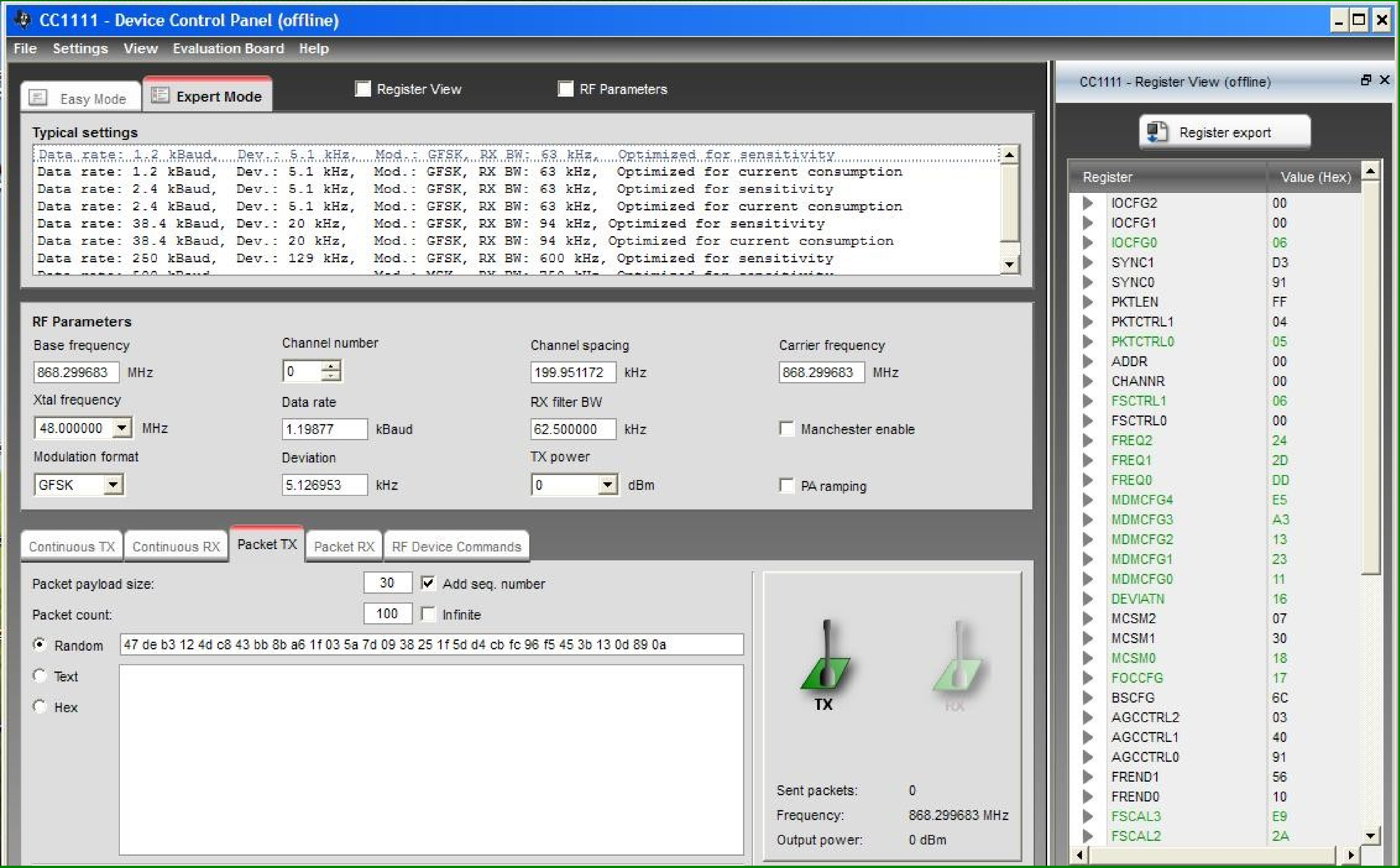
- IDLE
- CAL
- FSTXON
- RX
- TX


SIDLE
Default state when the radio is not receiving or transmitting.
Idle
SCAL
Used for calibrating frequency synthesizer upfront (entering receive or transmit mode can then be done quicker). Transitional state.
Manual freq. synth. calibration
SRX or STX or SFSTXON
Frequency synthesizer startup, optional calibration, settling
Frequency synthesizer is turned on, can optionally be calibrated, and then settles to correct frequency. Transitional state
SFSTXON
Frequency synthesizer is on, ready to start transmitting. Transmission starts very quickly after receiving the STX command strobe.
Frequency synthesizer on
STX
SRX
STX
TXOFF_MODE=01
SFSTXON or RXOFF_MODE=01
Transmit mode
Receive mode
STX or RXOFF_MODE=10
SRX or TXOFF_MODE=11
TXOFF_MODE=00
RXOFF_MODE=00
Optional transitional state.
Transmission is turned off and this state is entered if the RFD register becomes empty in the middle of a packet. Typ. current consumption: 1.8 mA
TX Overflow
Optional freq. synth. calibration
RX Overflow
Reception is turned off and this state is entered if the RFD register overflows.
SIDLE
SIDLE
Idle

0x2030 – cc1111 radio configuration

- configuring the radio is done through updating a set of 1-byte registers in varying bit-size fields
  - MDMCFG4 – MDMCFG0 – modem control
  - PKTCTRL1, PKTCTRL0 – packet control
  - FSCTRL1, FSCTRL0 – frequency synth control
  - FREND1, FREND0 – front end control
  - FREQ2, FREQ1, FREQ0 – base frequency
  - MCSM1, MCSM0 – radio state machine
  - SYNC1, SYNC0 – SYNC word, or the SFD
  - CHANNR, ADDR – channel and address
  - AGCCTRL2, AGCCTRL1, AGCCTRL0 – gain control

0x2040 - Smart RF Studio (ftw)



Typical settings

```
Data rate: 1.2 kBaud,  Dev.: 5.1 kHz,  Mod.: GFSK, RX BW: 63 kHz,  Optimized for sensitivity
Data rate: 1.2 kBaud,  Dev.: 5.1 kHz,  Mod.: GFSK, RX BW: 63 kHz,  Optimized for current consumption
Data rate: 2.4 kBaud,  Dev.: 5.1 kHz,  Mod.: GFSK, RX BW: 63 kHz,  Optimized for sensitivity
Data rate: 2.4 kBaud,  Dev.: 5.1 kHz,  Mod.: GFSK, RX BW: 63 kHz,  Optimized for current consumption
Data rate: 38.4 kBaud, Dev.: 20 kHz,   Mod.: GFSK, RX BW: 94 kHz, Optimized for sensitivity
Data rate: 38.4 kBaud, Dev.: 20 kHz,   Mod.: GFSK, RX BW: 94 kHz, Optimized for current consumption
Data rate: 250 kBaud,  Dev.: 129 kHz,  Mod.: GFSK, RX BW: 600 kHz, Optimized for sensitivity
```

RF Parameters

Base frequency	868.299683 MHz
Channel number	0
Channel spacing	199.951172 kHz
Carrier frequency	868.299683 MHz
Xtal frequency	48.000000 MHz
Data rate	1.19877 kBaud
RX filter BW	62.500000 kHz
Manchester enable	☐
Modulation format	GFSK
Deviation	5.126953 kHz
TX power	0 dBm
PA ramping	☐

Packet payload size: 30 ☑ Add seq. number

Packet count: 100 ☐ Infinite

● Random 47 de b3 12 4d c8 43 bb 8b a6 1f 03 5a 7d 09 38 25 1f 5d d4 cb fc 96 f5 45 3b 13 0d 89 0a

○ Text

○ Hex

Sent packets: 0

Frequency: 868.299683 MHz

Output power: 0 dBm

Register	Value (Hex)
IOCFG2	00
IOCFG1	00
IOCFG0	06
SYNC1	D3
SYNC0	91
PKTLEN	FF
PKTCTRL1	04
PKTCTRL0	05
ADDR	00
CHANNR	00
FSCTRL1	06
FSCTRL0	00
FREQ2	24
FREQ1	2D
FREQ0	DD
MDMCFG4	E5
MDMCFG3	A3
MDMCFG2	13
MDMCFG1	23
MDMCFG0	11
DEVIATN	16
MCSM2	07
MCSM1	30
MCSM0	18
FOCCFG	17
BSCFG	6C
AGCCTRL2	03
AGCCTRL1	40
AGCCTRL0	91
FREND1	56
FREND0	10
FSCAL3	E9
FSCAL2	2A

0x2050 – cc1111 radio notes

- Data Rate, Bandwidth, and Intermediate Frequency and Freq-Deviation depend on each other

- put the radio in IDLE state before configuring
- put the radio in IDLE state before configuring
- put the radio in IDLE state before configuring

- STROBE (SIDLE, STX, SRX, SCAL...)
  - then wait for the MARCSTATE == MARC_STATE_whatever
- CCA impacts entering TX state from RX
  - but not from IDLE state

0x2060 – usb

- usb is a world unto itself, with a massive standard and substandards
  - gg: usb-in-a-nutshell
  - gg: usb complete jan axelson
- cc1111's usb controller is accessed using:
  - registers for config/control of usb
  - registers indicating usb events that occur
  - endpoint-specific FIFO buffers
    - messages go there before sending to host
    - messages arrive there from host
  - usb “descriptors” as necessary by spec
    - host uses these to query the device
- our firmware provides all this and more

0x2100 – RfCat for devs

- cc1111usb.c provides usb descriptors and framework
  - shouldn't need much tinkering
- cc1111rf.c provides the core of the radio firmware
  - shouldn't need much tinkering
- application.c provides the template for new apps
  - copy it and make your amazing toy
- txdata(buffer, length) to send data IN to host
- registerCbEP5OUT() to register a callback function to handle data OUT from host
  - data is in ep5iobuf[]
- transmit(*buf, length) allows you to send on the RF pipeline
- appMainLoop() – modify this for handling RF packets, etc...
- follow the examples, luke!
  - RfCat's “application” source is appFHSSNIC.c

0xE3 – heartfelt communication

- pick a friend (or set of friends)
- agree on who will xmit and who will recv

```
$ rfcat -r                # common (xmit/recv)
>>> d.setMdmModulation(MOD_GFSK)
>>> d.makePktFLEN(20)
>>> d.setFreq( 915200000 )
--- recver ---
>>> d.RFlisten()
--- xmitter ---
>>> d.RFxmit(“hello my name is <name>”)
```

- what happened?

0xE3.5 – your closer friends...

- two problems: length and sync word!
- both xmitter and recver (not necessarily at once):
  - increase the packet length

```
>>> d.makePktFLEN(35)  #what happens when transmitting now?
```

  - now agree upon a 16-bit sync word (0 – 0xffff)

```
>>> d.setMdmSyncWord(<syncword>)
```

  - now try xmit/recv again
  - now reverse roles
  - now learn the power of the dark side!

```
>>> d.discover()
>>> d.discover(IdentSyncWord=True)
>>> help(d)      # ahhhhhhh.....
```

0x3000 – inquiring minds want to know!

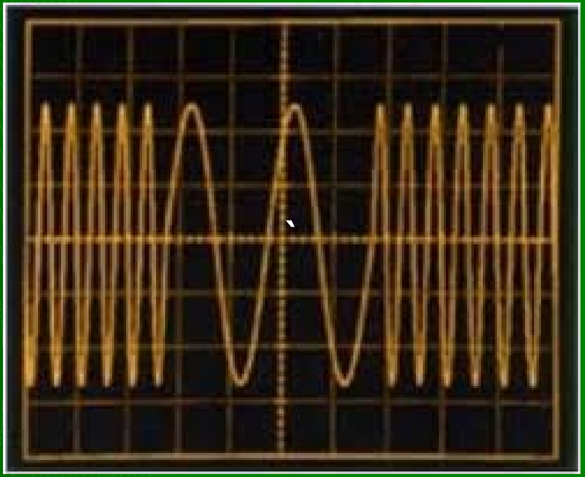
- frequencies
- modulation (2FSK/GFSK, MSK, ASK/OOK, other)
- intermediate frequency (IF)
- baud rate
- channel width/spacing/hopping?
- bandwidth filter
- sync words / bit-sync
- variable length/fixed length packets
- crc
- data whitening?
- any encoding (manchester, fec, enc, etc...)

0x3010 – interesting frequencies

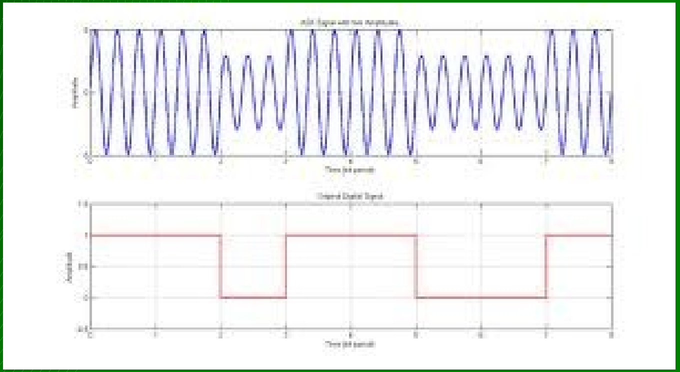
- 315MHz – car fobs, garage door openers
- 433MHz – medical devices, car fobs
- 868MHz – EU loves this range
- 915MHz – NA stuff of all sorts (power meters, insulin pumps, industrial plant equipment, industrial backhaul)

- (the rest are not covered by RfCat... yet)
- 2.4GHz – 802.11/wifi, 802.15.4/zigbee/6lowpan, bluetooth
- 5.8GHz – cordless phones
- FREQ2, FREQ1, FREQ0

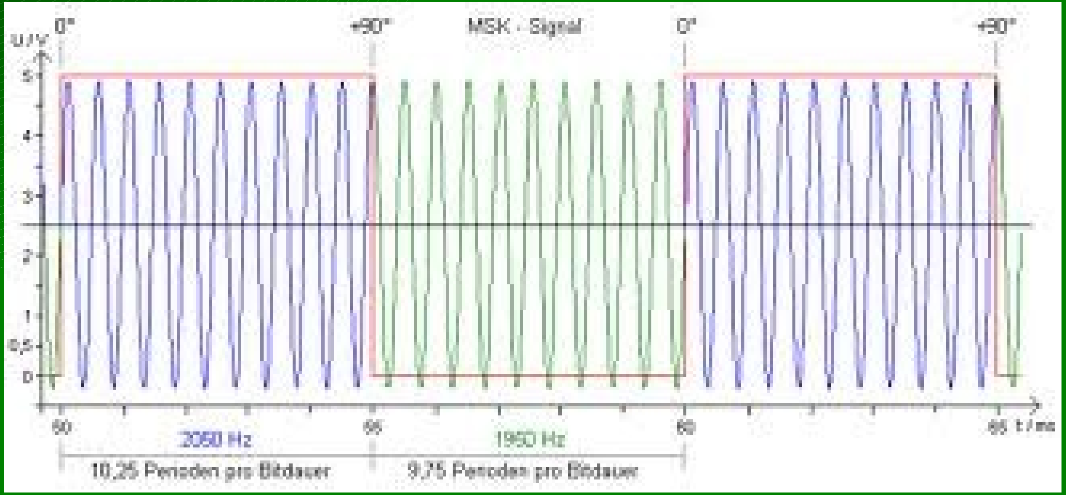
0x3020 – modulations



- 2FSK/GFSK – Frequency Shift Key
  - (digital FM)
  - power meters, DECT/CT2



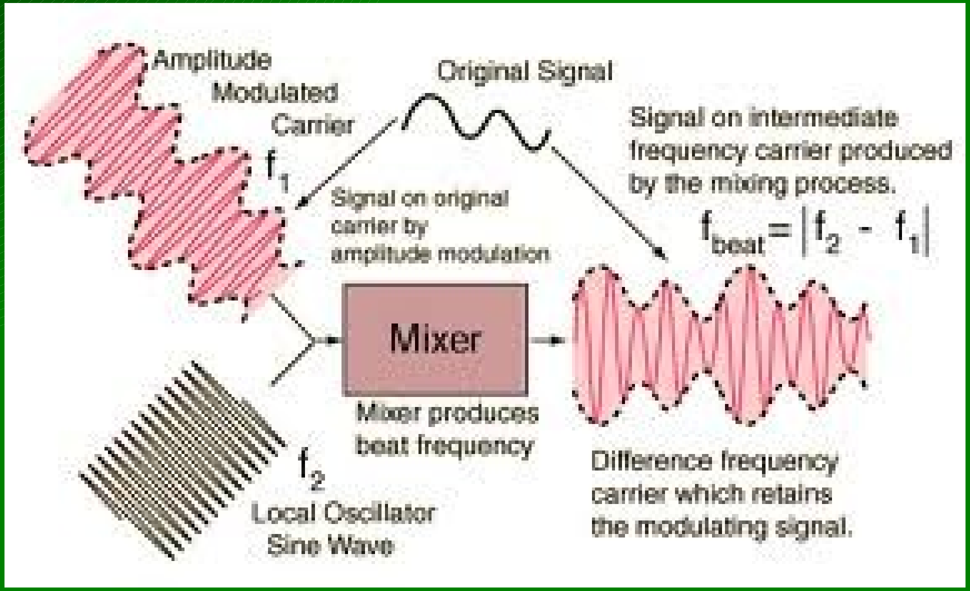
- ASK/OOK – Amplitude Shift Key
  - (digital AM)
  - morse-code, car-remotes, etc...
- MSK – Minimal Shift Key (a type of quadrature shift modulation like QPSK)
  - GSM



- MDMCFG2, DEVIATN

0x3030 – intermediate frequency

- mix the RF and LO frequencies to create an IF (heterodyne)
  - improves signal selectivity
  - tune different frequencies to an IF that can be manipulated easily
  - cheaper/simpler components
- cc1111 supports a wide range of 31 different IF options:
  - 23437 hz apart, from 0 – 726.5 khz
- Smart RF Studio recommends:
  - 140 khz up to 38.4 kbaud
  - 187.5 khz at 38.4 kbaud
  - 281 khz at 250 kbaud
  - 351.5khz at 500 kbaud
- FSCTRL1


Amplitude Modulated Carrier
f_1
Original Signal
Signal on original carrier by amplitude modulation
Signal on intermediate frequency carrier produced by the mixing process.
$f_{beat} = |f_2 - f_1|$
Mixer
Mixer produces beat frequency
f_2
Local Oscillator Sine Wave
Difference frequency carrier which retains the modulating signal.

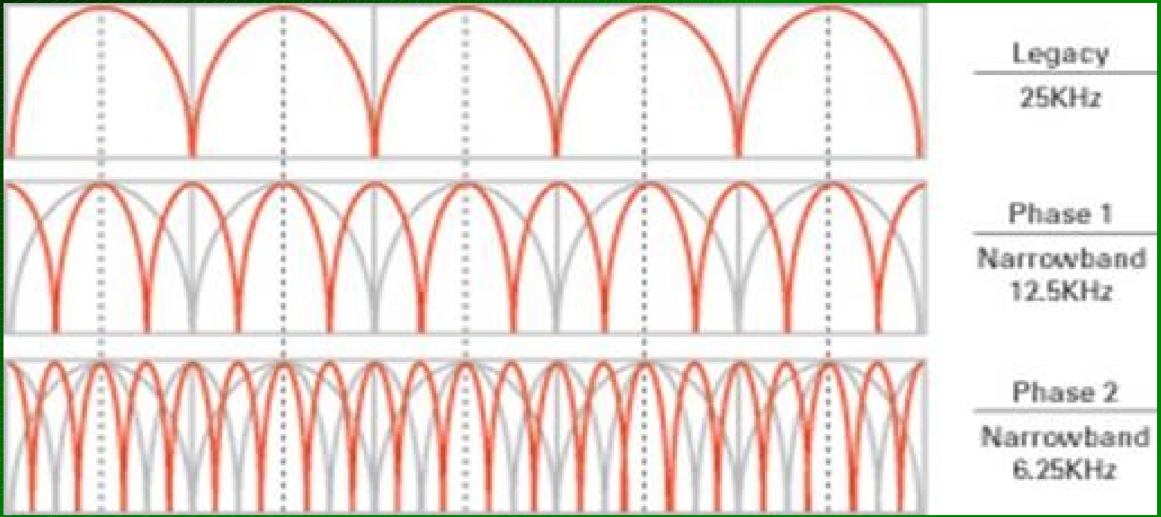
0x3040 – data rate (baud)

- much like your modems or old
- the frequency of bits
  - some can overlap and get garbage!
    - garbage can be good...
- baud has significant impact on IF, Deviation and Channel BW
- seeing much use of 2400, 19200, 38400, 250000
  - and other oddballs like 4760
- MDMCFG3 / 4

0x3050 – channel width / spacing

- simplifying frequency hopping / channelized systems
- real freq = base freq + (CHANNR * width)

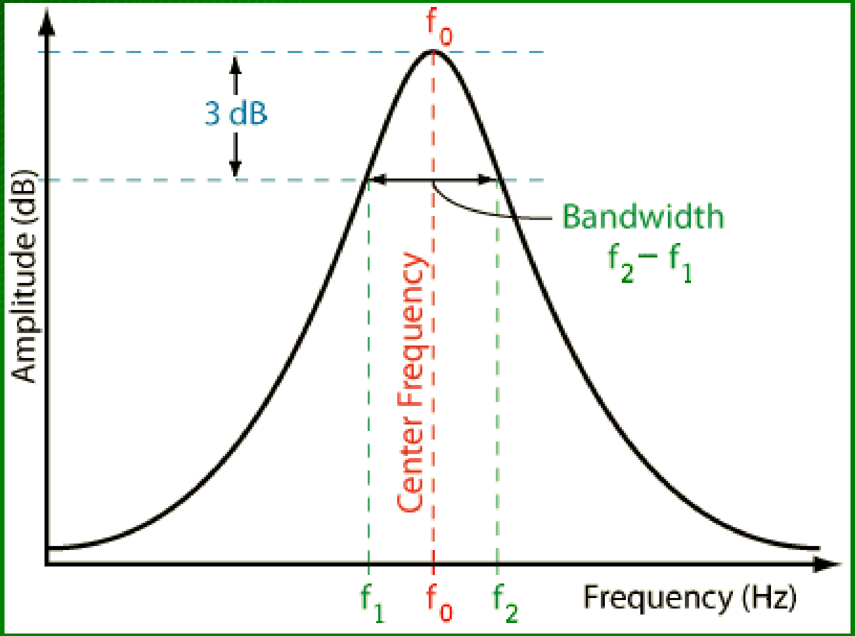
- MDMCFG0 / 1



0x3060 – bandwidth filter

- programmable receive filter
- provides for flexible channel sizing/spacing

- total signal bw = signal bandwidth + (2*variance)
- total signal bw **wants** to be less than 80% bw filter!
- MDMCFG4



0x3070 – preamble / sync words

- identify when real messages are being received!
- starts out with a preamble (1 0 1 0 1 0 1 0...)
- then a sync word (programmable bytes)
  - marking the end of the preamble
  - aka 'SFD' – start of frame delimiter
- configurable to:
  - nothing (just dump received crap)
  - carrier detect (if the RSSI value indicates a message)
  - 15 or 16 bits of the SYNC WORD identified
  - 30 out of 32 bits of double-SYNC WORD
- SYNC1, SYNC0, MDMCFG2

0x3080 – variable / fixed-length packets

- packets can be fixed length or variable length
- variable length assumes first byte is the length byte
- both modes use the PKTLEN register:
  - Fixed: the length
  - Variable: MAX length
- soon, with contributions from Major Malfunction:
  - Infinite mode (very long FIXED length, eg. 1024)

- PKTCTRL0, PKTLEN

0x3090 – CRC – duh, but not

- crc16 check on both TX and RX
- uses the internal CRC (part of the RNG) seeded by 0xffff
- DATA_ERROR flag triggers when CRC is enabled and fails
- some systems do this in firmware instead

- PKTCTRL0

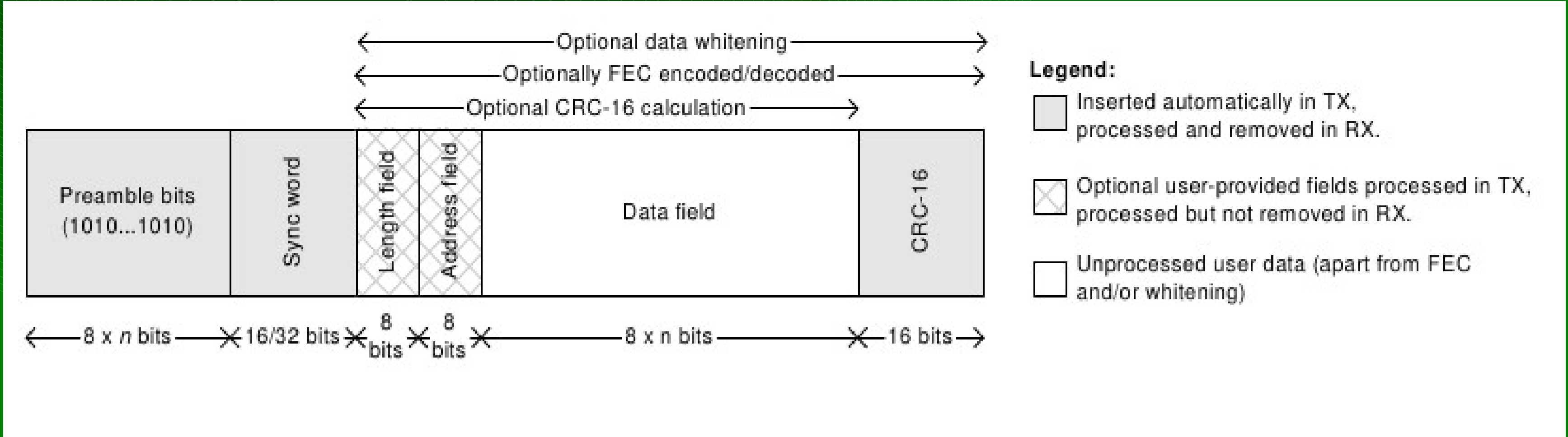
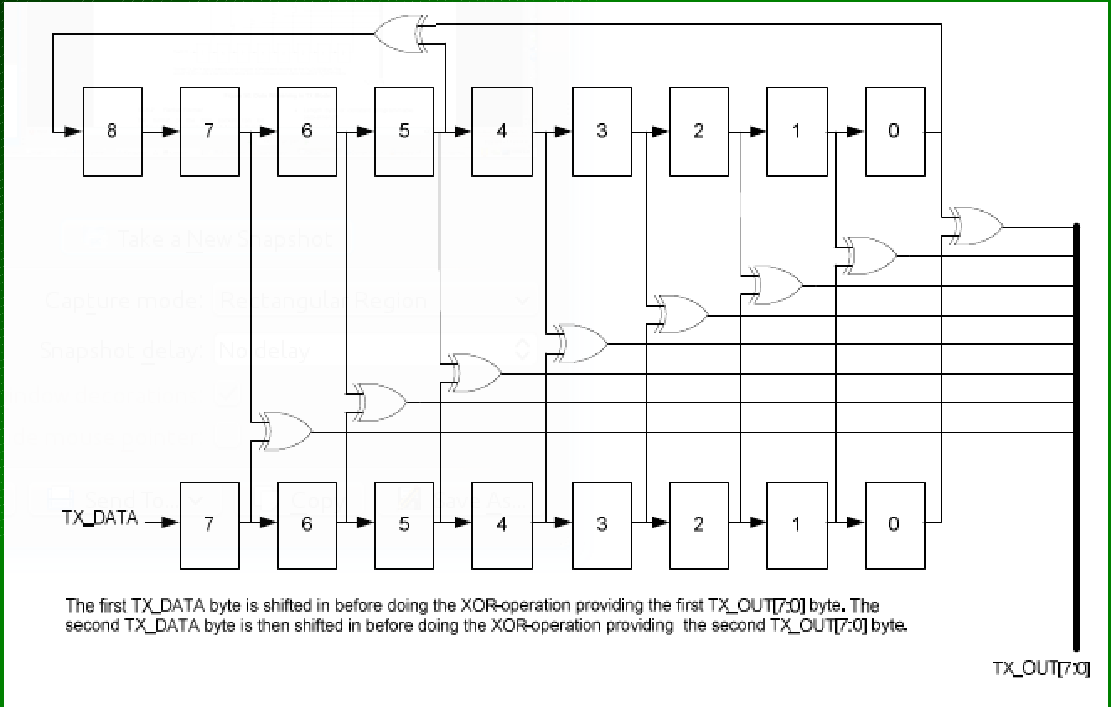

Optional data whitening
Optionally FEC encoded/decoded
Optional CRC-16 calculation
Preamble bits (1010...1010)
Sync word
Length field
Address field
Data field
CRC-16
8 x n bits
16/32 bits
8 bits
8 bits
8 x n bits
16 bits
Legend:
Inserted automatically in TX, processed and removed in RX.
Optional user-provided fields processed in TX, processed but not removed in RX.
Unprocessed user data (apart from FEC and/or whitening)

Figure 51: Packet Format

0x30a0 – data whitening – 9 bits of pain

- ideal radio data looks like random data
- real world data can contain long sequences of 0 or 1
- data to be transmitted is first XOR'd with a 9-bit sequence
  - sequence repeated as many times as necessary
- PKTCTRL0

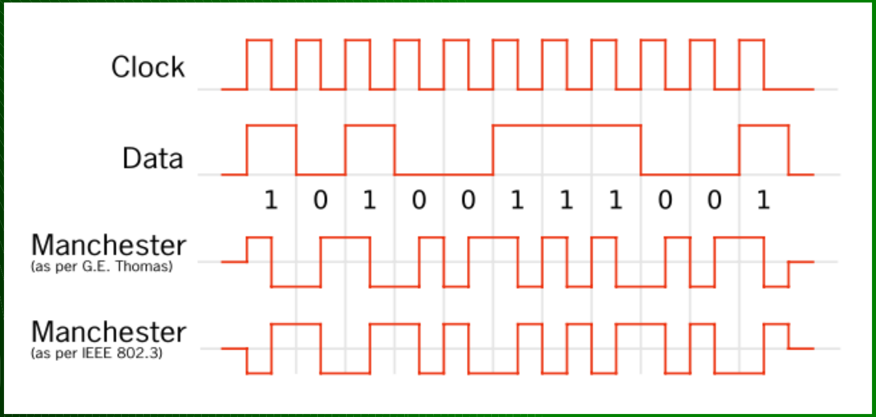


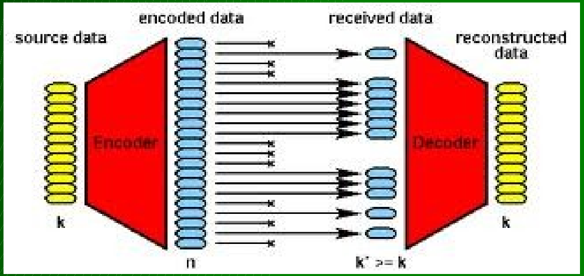
The first TX_DATA byte is shifted in before doing the XOR-operation providing the first TX_OUT[7:0] byte. The second TX_DATA byte is then shifted in before doing the XOR-operation providing the second TX_OUT[7:0] byte.

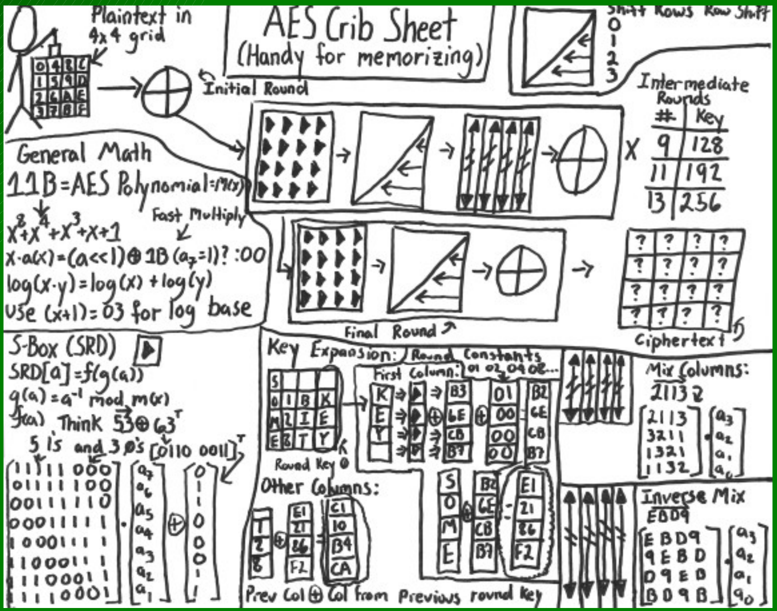
Figure 50: Data Whitening in TX Mode

0x30b0 – encoding

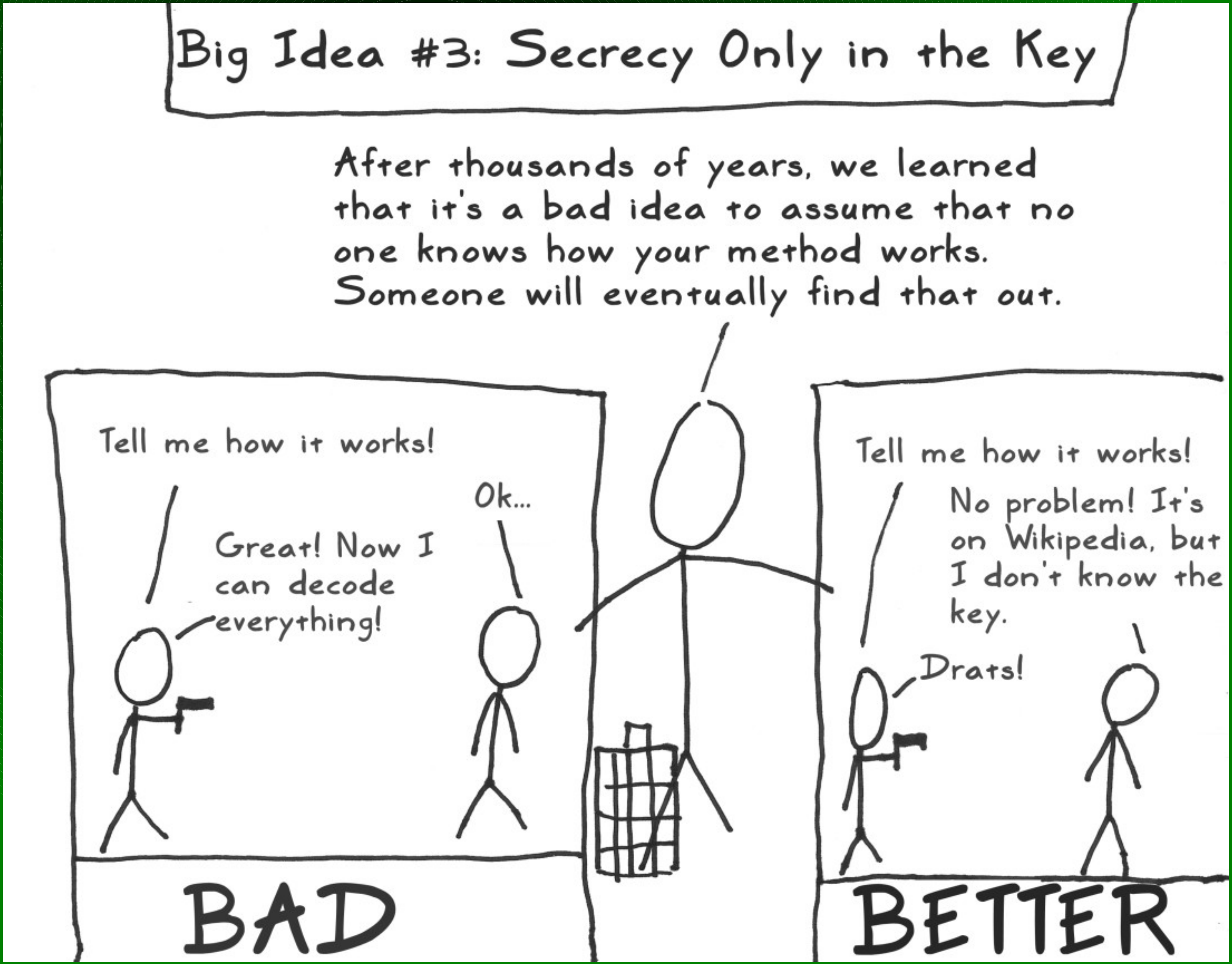
- manchester
  - MDMCFG2
- forward error correction
  - convolutional
    - MDMCFG1
  - reed-solomon (not supported)
- encryption - AES in chip







sorry, couldn't resist


Big Idea #3: Secrecy Only in the Key
After thousands of years, we learned that it's a bad idea to assume that no one knows how your method works. Someone will eventually find that out.
Tell me how it works!
Ok...
Great! Now I can decode everything!
BAD
Tell me how it works!
No problem! It's on Wikipedia, but I don't know the key.
Drats!
BETTER

0xE4 - mismatching

- xmitter and recver pick the same config (last ej)
- select random quiet frequency (same as each other)
- xmitter change something (see below) and transmit, talk to recver (use your mouth) to discuss results
  - change modulation, then transmit

```
>>> d.setMdmModulation(MOD_*)
 (MOD_ASK_OOK, MOD_GFSK, MOD_2FSK, MOD_MSK)
```

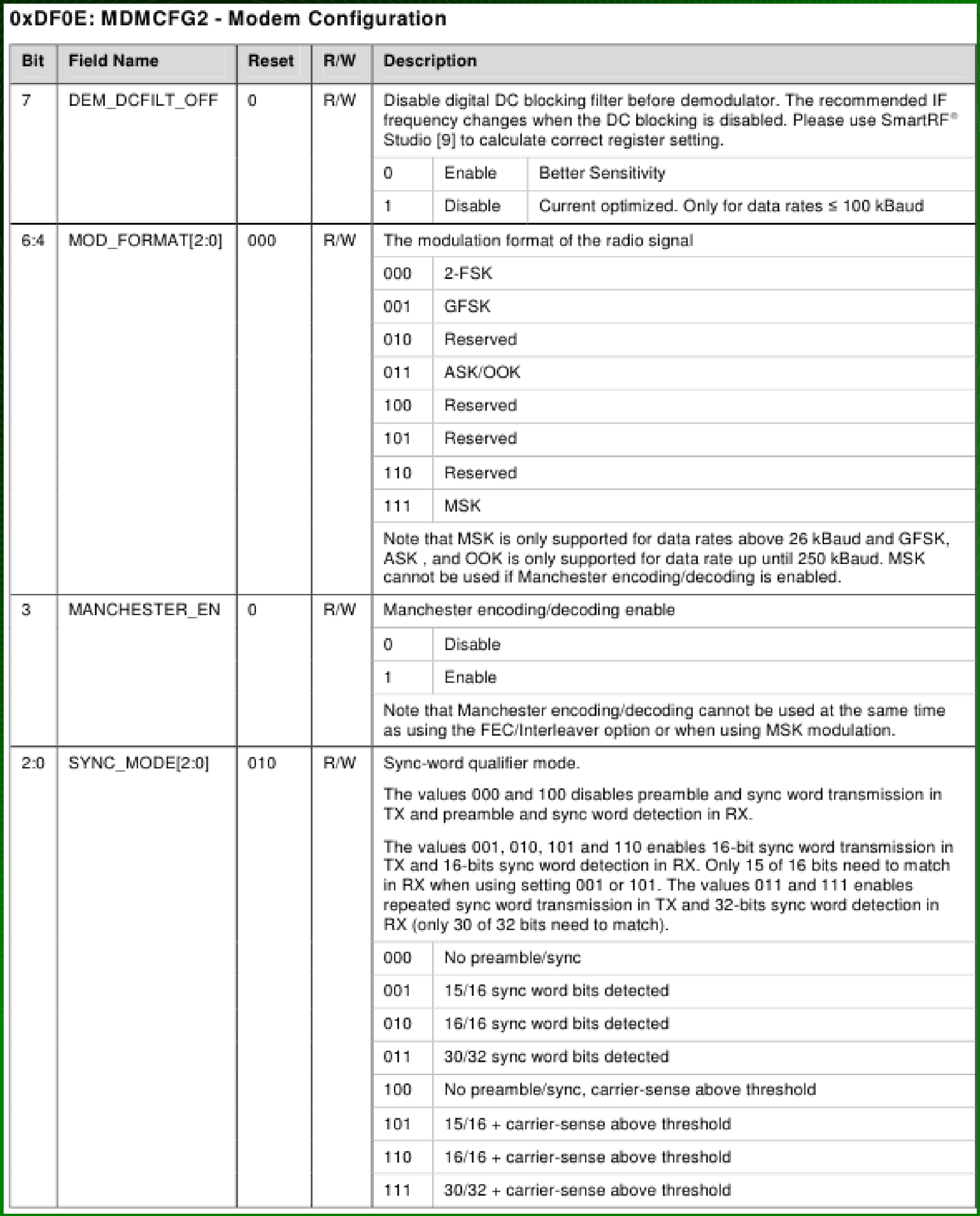
  - resync (so you are the same) and change baud rate

```
>>> d.setMdmDRate (baud)
```

  - etc...

```
>>> d.setMdmDeviatn(<deviation_number>)

>>> d.makePktFLEN() and d.makePktVLEN()  # vary len too!

>>> d.makePktFLEN(32) and d.makePktVLEN(0xff)
```

0x30c0 – MDMCFG2 register (example)



0xDF0E: MDMCFG2 - Modem Configuration

Bit	Field Name	Reset	R/W	Description		
7	DEM_DCFILT_OFF	0	R/W	Disable digital DC blocking filter before demodulator. The recommended IF frequency changes when the DC blocking is disabled. Please use SmartRF® Studio [9] to calculate correct register setting.		
				0	Enable	Better Sensitivity
				1	Disable	Current optimized. Only for data rates ≤ 100 kBaud
6:4	MOD_FORMAT[2:0]	000	R/W	The modulation format of the radio signal		
				000	2-FSK	
				001	GFSK	
				010	Reserved	
				011	ASK/OOK	
				100	Reserved	
				101	Reserved	
				110	Reserved	
				111	MSK	
				Note that MSK is only supported for data rates above 26 kBaud and GFSK, ASK , and OOK is only supported for data rate up until 250 kBaud. MSK cannot be used if Manchester encoding/decoding is enabled.		
3	MANCHESTER_EN	0	R/W	Manchester encoding/decoding enable		
				0	Disable	
				1	Enable	
				Note that Manchester encoding/decoding cannot be used at the same time as using the FEC/Interleaver option or when using MSK modulation.		
2:0	SYNC_MODE[2:0]	010	R/W	Sync-word qualifier mode. The values 000 and 100 disables preamble and sync word transmission in TX and preamble and sync word detection in RX. The values 001, 010, 101 and 110 enables 16-bit sync word transmission in TX and 16-bits sync word detection in RX. Only 15 of 16 bits need to match in RX when using setting 001 or 101. The values 011 and 111 enables repeated sync word transmission in TX and 32-bits sync word detection in RX (only 30 of 32 bits need to match).		
				000	No preamble/sync	
				001	15/16 sync word bits detected	
				010	16/16 sync word bits detected	
				011	30/32 sync word bits detected	
				100	No preamble/sync, carrier-sense above threshold	
				101	15/16 + carrier-sense above threshold	
				110	16/16 + carrier-sense above threshold	
				111	30/32 + carrier-sense above threshold	

0x3100 – how can we figure it out!?

- open / public documentation
  - insulin pump published frequency
- open source implementation / source code
- “public” but harder to find (google fail!)
  - fcc.gov – search for first part of FCC ID
    - http://transition.fcc.gov/oet/ea/fccid/ -bookmark it
  - patents – amazing what people will patent!
    - http://freepatentsonline.com
    - french patent describing the whole MAC/PHY of one meter
    - and another:
      http://www.freepatentsonline.com/8189577.html
      http://www.freepatentsonline.com/20090168846.pdf

0x3101 – how can we figure it out!? -part2

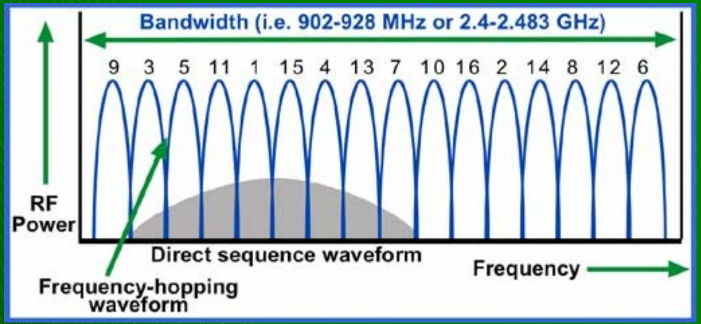
- reversing hw
  - tapping bus lines – logic analyzer
    - grab config data
    - grab tx/rx data
  - pulling and analyzing firmware
- hopping pattern analysis
  - arrays of dongles – space them out and record results
  - hedyattack, or something similar
  - spectrum analyzer
  - USRP2 or latest gadget from Michael Ossman
- trial and error – rf parameters
- MAC layer? - takes true reversing.. unless you find a patent :)

0xE5 – spectrum analysis

```
>>> d.specan(902000000, 50000, 150)
```

<close the spectrum analysis window to end this mode>

0x4000 – intro to FHSS



- FHSS is common for devices in the ISM bands
  - provides natural protection against unintentional jamming /interferance
  - US Title 47 CFR 15.247 affords special power considerations to FHSS devices
    - >25khz between channels
    - pseudorandom pattern
    - each channel used equally (avg) by each transmitter
    - if 20db of hopping channel < 250khz:
      - must have at least 50 channels
      - average <0.4sec per 20 seconds on one channel
    - if 20dB of hopping channel >250khz:
      - must have at least 25 channels
      - average <0.4sec per 10 seconds on one channel

0x4010 – FHSS, the one and only - NOT!

- different technologies:
  - DSSS – Direct Sequence Spread Spectrum
    - hops happen more often than bytes (ugh)
    - typically requires special PHY layer
  - “FHSS”
    - hops occur after a few symbols are transmitted
- different topologies: (allow for different synch methods)
  - point-to-point (only two endpoints)
  - multiple access systems (couple different options)
    - each cell has their own hopping pattern
    - each node has own hopping pattern
- different customers:
  - military has used frequency hopping since Hedy and George submitted the patent in 1941.
  - commercial folks (WiFi, Bluetooth, proprietary stuff like power meters)

0x4020 – FHSS intricacies

- what's so hard about FHSS?
  - must know or be able to come up with the hopping pattern
    - can be anywhere from 50 to a million distinct channel hops before the pattern repeats (or more)
    - some systems use one pattern per cell, others per node
  - must be able to synchronize with an existing cell or partner
    - or become your own master!
  - must know how to discover other nodes (
  - must know channel spacing
  - must know channel dwell time (time to sit on each channel)
  - likely need to reverse engineer your target
  - DSSS (eg. Bluetooth) requires that you have special hardware
- military application will be very hard to crack, as it typically will have hops based on a synchronized PRNG to select channels

0x4030 – FHSS, the saving graces

- any adhoc FHSS multi-node network: (power meters / sensor-nets)
  - node sync in a reasonable timeframe
    - limited channels in the repeated pattern
  - each node knows how to talk to a cell
    - let one figure it out, then tap the SPI bus to see what the pattern is...
- two keys to determining hopping pattern:
  - hop pattern generation algorithm
    - often based on the CELL ID
      - one pattern gets you the whole cell :)
    - others generate a unique pattern per node
  - some sync information the cell gives away for free
    - gotta tell the n00bs how to sync up, right?
    - for single-pass repeating sequences, it's just the channel

0x4040 – FHSS summary

- FHSS comes in different forms for different uses and different users
- FHSS is naturally tolerant to interference, and allows a device to transmit higher power than nonFHSS comms
- getting the FHSS pattern, timing, and appropriate sync method for proprietary comms can be a reversing challenge
- getting a NIC to do something with the knowledge gained above has – to date – been very difficult

0x5000 – intro to RfCat

- RfCat: RF Chipcon-based Attack Toolset
- background...
- goals...
- plans...
- where we're at so far...

0x5010 – rfcat background

- the power grid
  - power meters and the folks who love them (yo cutaway, q, travis and josh!)
  - no availability of good attack tools for RF
- vendor at Distributech 2008:

  "Our Frequency Hopping Spread Spectrum is too fast for hackers to attack."

  - OMFW! really?

0x5020 – rfcat goals

- RE tools - “how does this work?”
- security analysis tools - “your FHSS and Crypto is weak!”
- satiate my general love of RF

- a little of Nevil Maskelyne
- “I will not demonstrate to any man who throws doubt upon the system” - Guglielmo Marconi, 1903
  - lulwut?

0x5030 – this is not HedyAttack

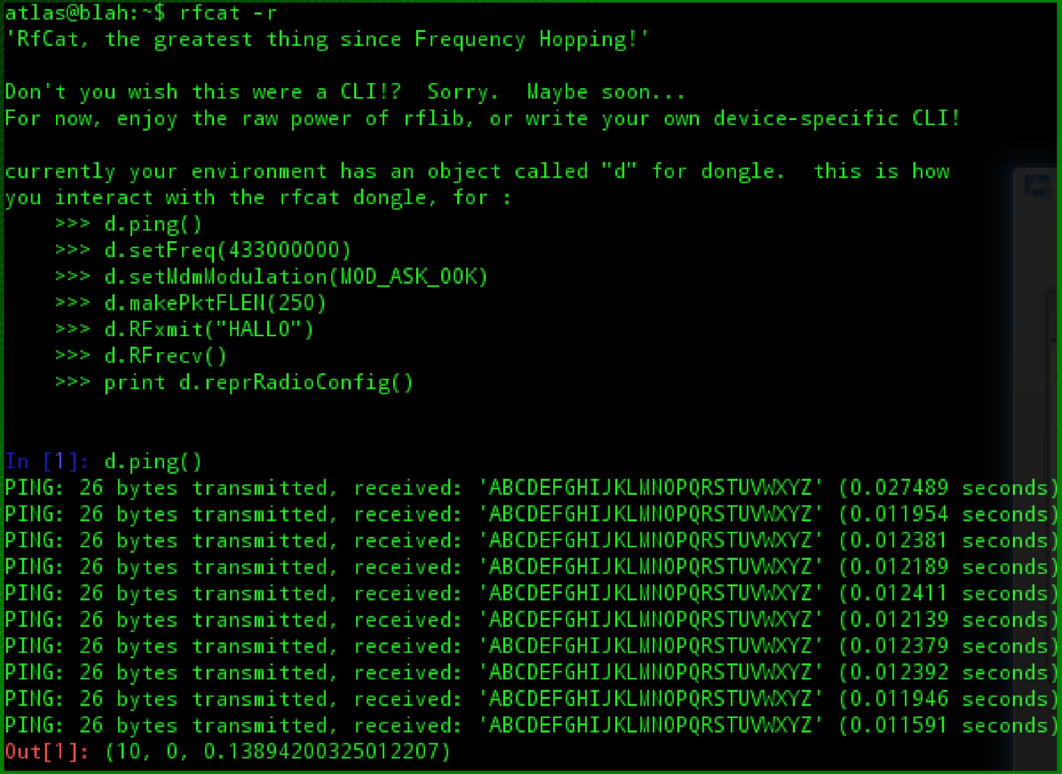
- but leveraged the knowledge from HA...
- cc1111usb is the base code which HedyAttack started
  - forms the USB base for RfCat
- less "researchy"
  - this project won't **find** hopping patterns
  - it's goal is to provide you something to do with that infoz
    - “so, we determined this hopping pattern... now what?”
- more utilitarian
  - give us comms parameters and a hopping pattern, and we'll be a NIC, sniffer, and interact with RF gadgets
  - some devices will require more customization than other

0x5040 – rfcat's interface

- rfcat is many things, but I like to think of it as an interactive python access to the <GHz spectrum!
- rfcat
  - FHSS-capable NIC
    - some assembly may be required for FHSS to arbitrary devices
  - toolset for discovering/interfacing with RF devices
- rfcat_server
  - access the <GHz band over an IP network or locally
  - connect to tcp port 1900 for raw data channel
  - configure on the fly (TCP port 1899)

0x5050 – rfcat

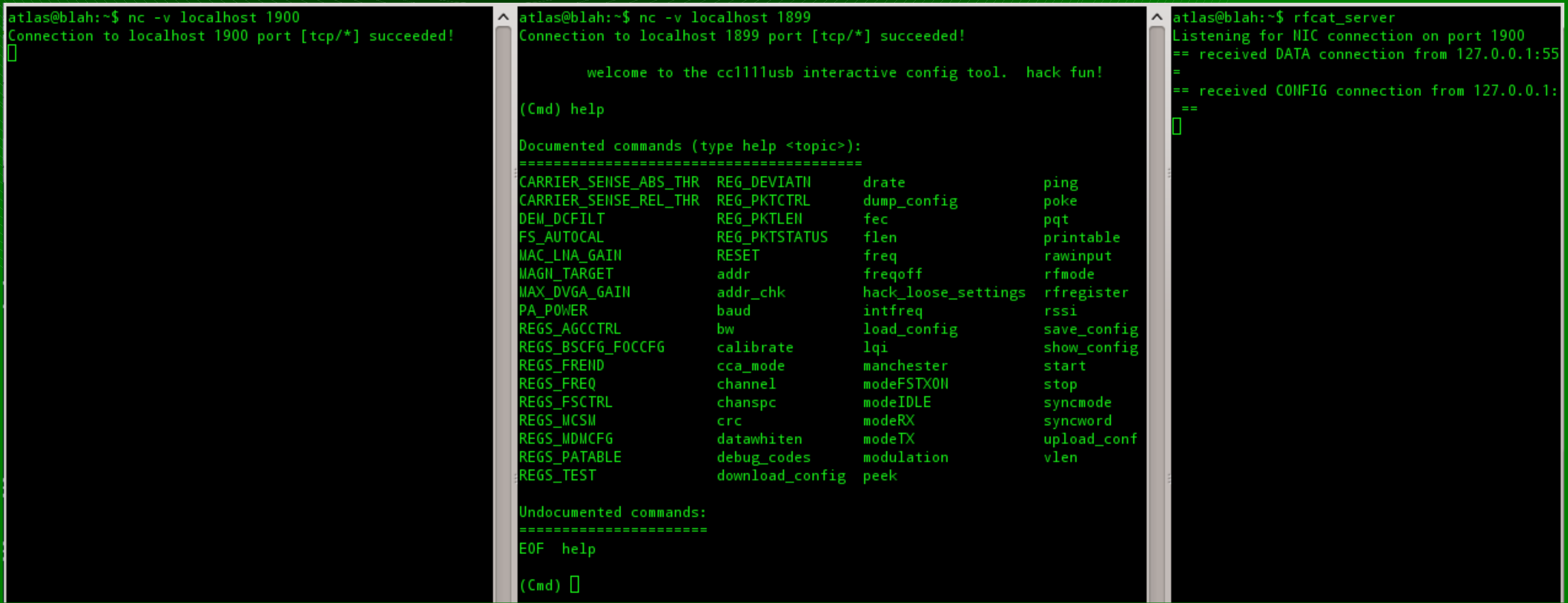
- customizable NIC-access to the ISM bands
- currently lame “default” interface
- “research mode” is where the power is...
- ipython for best enjoyment
- lame spoiler: you get a global object called “d” to talk to RfCat
  - d.RFxmit('blah')
  - data = d.RFrecv()
  - d.discover(lowball=1)
  - d.RFlisten()/d.RFcapture()
  - d.specan()
  - help(d)



```
atlas@blah:~$ rfcat -r
'RfCat, the greatest thing since Frequency Hopping!'

Don't you wish this were a CLI!?  Sorry.  Maybe soon...
For now, enjoy the raw power of rflib, or write your own device-specific CLI!

currently your environment has an object called "d" for dongle.  this is how
you interact with the rfcat dongle, for :
    >>> d.ping()
    >>> d.setFreq(433000000)
    >>> d.setMdmModulation(MOD_ASK_OOK)
    >>> d.makePktFLEN(250)
    >>> d.RFxmit("HALLO")
    >>> d.RFrecv()
    >>> print d.reprRadioConfig()


In [1]: d.ping()
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.027489 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.011954 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.012381 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.012189 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.012411 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.012139 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.012379 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.012392 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.011946 seconds)
PING: 26 bytes transmitted, received: 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' (0.011591 seconds)
Out[1]: (10, 0, 0.13894200325012207)
```

0x5060 – rfcat_server

- bringing <GHz over the IP network!
- connect on TCP port 1900 to access the wireless network
- connect on TCP port 1899 to access the wireless configuration
- created to allow non-python clients to play too
  - stdin is not always the way you want to interact with embedded wireless protocols



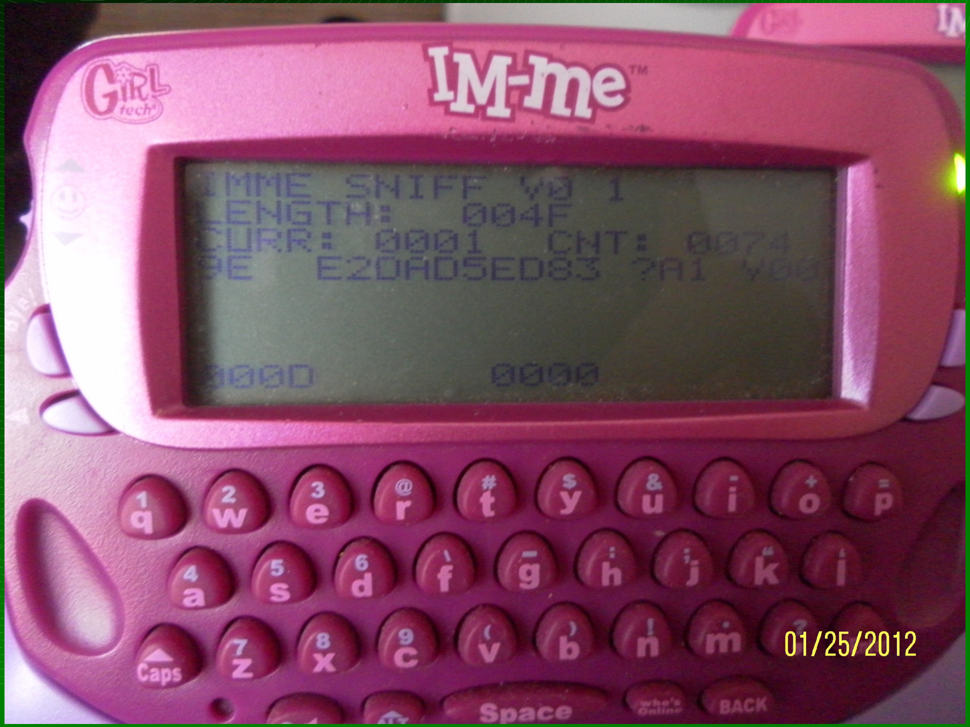
```
atlas@blah:~$ nc -v localhost 1900
Connection to localhost 1900 port [tcp/*] succeeded!
```

```
atlas@blah:~$ nc -v localhost 1899
Connection to localhost 1899 port [tcp/*] succeeded!

        welcome to the cc1111usb interactive config tool.  hack fun!

(Cmd) help

Documented commands (type help <topic>):
========================================
CARRIER_SENSE_ABS_THR  REG_DEVIATN      drate                ping
CARRIER_SENSE_REL_THR  REG_PKTCTRL      dump_config          poke
DEM_DCFILT             REG_PKTLEN       fec                  pqt
FS_AUTOCAL             REG_PKTSTATUS    flen                 printable
MAC_LNA_GAIN           RESET            freq                 rawinput
MAGN_TARGET            addr             freqoff              rfmode
MAX_DVGA_GAIN          addr_chk         hack_loose_settings  rfregister
PA_POWER               baud             intfreq              rssi
REGS_AGCCTRL           bw               load_config          save_config
REGS_BSCFG_FOCCFG      calibrate        lqi                  show_config
REGS_FREND             cca_mode         manchester           start
REGS_FREQ              channel          modeFSTXON           stop
REGS_FSCTRL            chanspc          modeIDLE             syncmode
REGS_MCSM              crc              modeRX               syncword
REGS_MDMCFG            datawhiten       modeTX               upload_conf
REGS_PATABLE           debug_codes      modulation           vlen
REGS_TEST              download_config  peek

Undocumented commands:
======================
EOF  help

(Cmd) 
```

```
atlas@blah:~$ rfcat_server
Listening for NIC connection on port 1900
== received DATA connection from 127.0.0.1:55
=
== received CONFIG connection from 127.0.0.1:
 ==
```

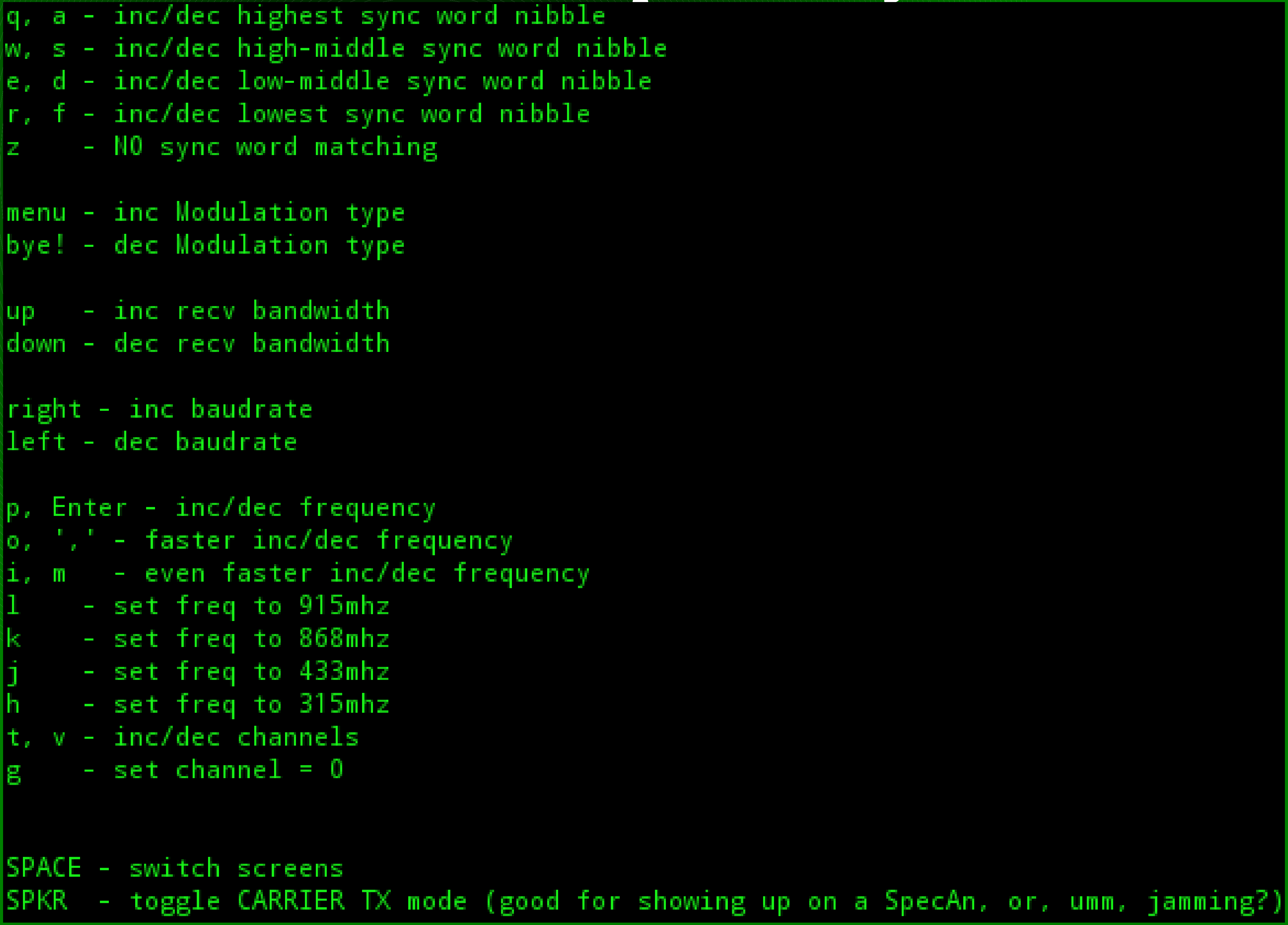
0x5070 – rfsniff (pink version too!)

- focused primarily on capturing data from the wireless network
- IMME used to provide a nice simple interface
- RF config adjustment using keyboard!



```
IMME SNIFF V0 1
LENGTH:   004F
CURR: 0001  CNT: 0074
9E  E2DAD5ED83 ?A1 V00


000D        0000
```

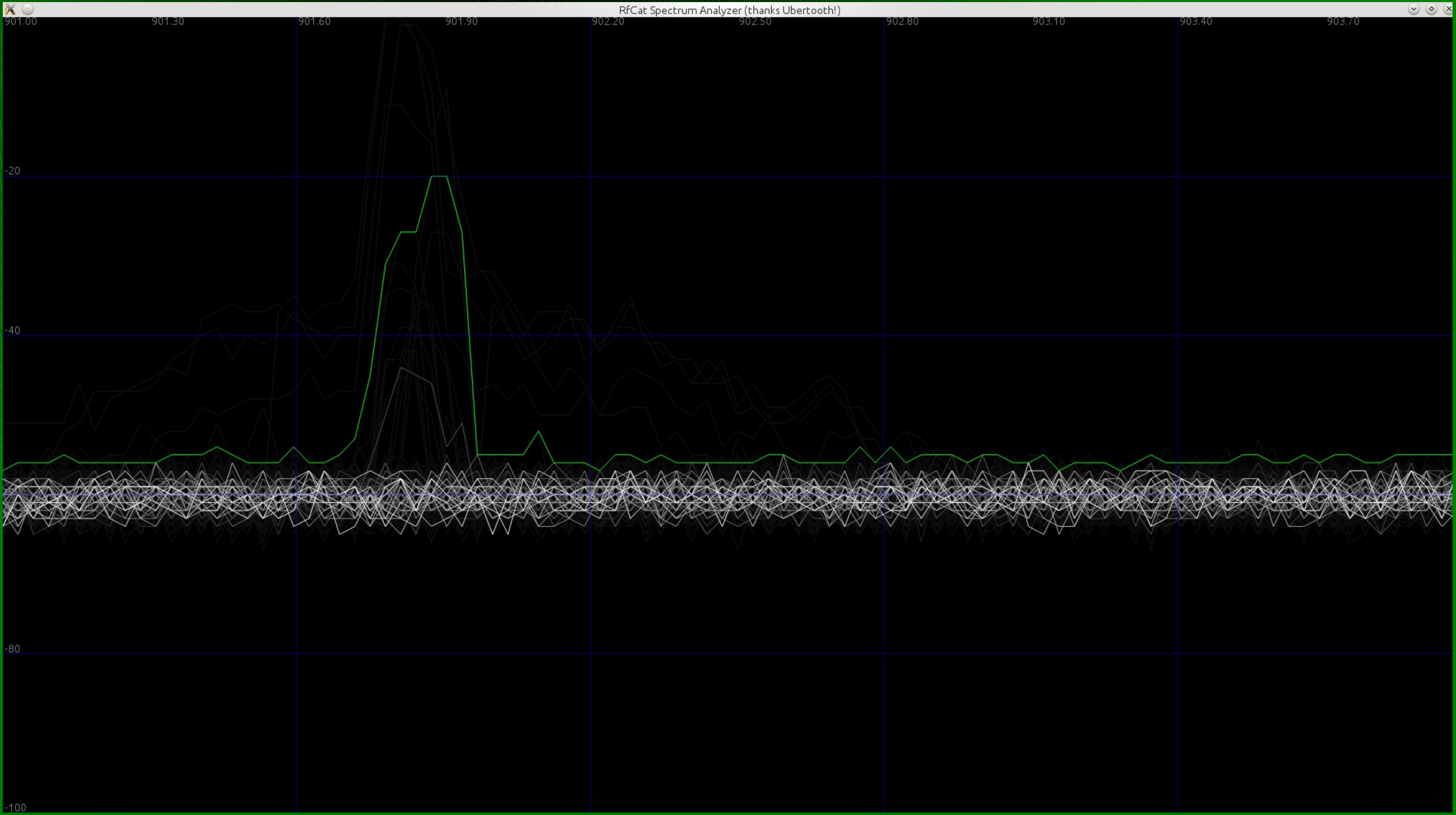
0x5065 – rfsniff – key bindings



```
q, a - inc/dec highest sync word nibble
w, s - inc/dec high-middle sync word nibble
e, d - inc/dec low-middle sync word nibble
r, f - inc/dec lowest sync word nibble
z    - NO sync word matching

menu - inc Modulation type
bye! - dec Modulation type

up   - inc recv bandwidth
down - dec recv bandwidth

right - inc baudrate
left - dec baudrate

p, Enter - inc/dec frequency
o, ',' - faster inc/dec frequency
i, m   - even faster inc/dec frequency
l    - set freq to 915mhz
k    - set freq to 868mhz
j    - set freq to 433mhz
h    - set freq to 315mhz
t, v - inc/dec channels
g    - set channel = 0


SPACE - switch screens
SPKR  - toggle CARRIER TX mode (good for showing up on a SpecAn, or, umm, jamming?)
```

0x5070 – spectrum analaysis (added 7/21/12)

```
>>> d.specan(901e6, 5e5, 51)
```



0x5075 – specan limitations

- currently SpecAn uses Channel mode
  - lowest channel spacing: ~23.4khz
  - highest channel spacing: 250khz
- currently SpecAn limits number of sampled freqs to 255
  - recommend 100 or so samples
- still... not bad.
- many thanks to the ubertooth team for the GUI base!

0xE6 – lowball, discovery, and scanning

- enter lowball mode (which stores config)

```
>>> d.lowball()      # (SYNCM_CARRIER)
>>> print d.reprClientState()
>>> d.lowballRestore()   # restore the config
>>> d.RFrecv()  # and again, until you receive a timeout error
```

- now use lowball level 0:

```
>>> d.lowball(0)    # dumps all sorts of crap (SYNCM_NONE)
>>> print d.reprRadioConfig()
>>> d.lowballRestore() # restores original config
>>> d.RFrecv()      # grab raw packet
>>> d.recvAll(APP_NIC, NIC_RECV) # dump all buffered pkts
```

0xE6.1 – discover mode

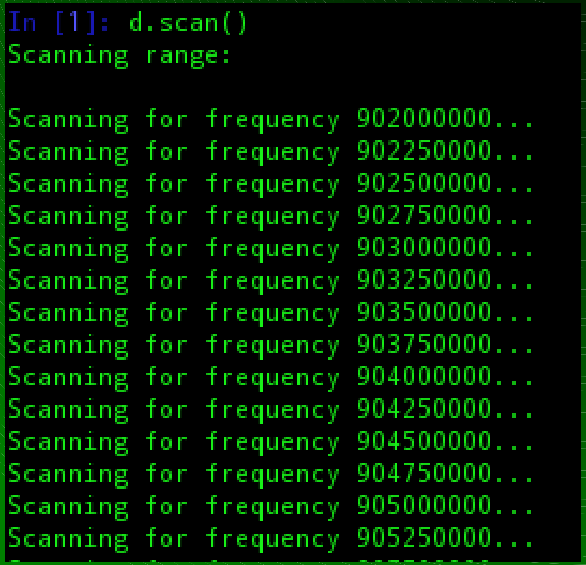
- now use discover()

```
>>> d.discover()    # press <enter> to leave discover mode
>>> d.discover(lowball=0)    # what do you see?
>>> d.discover(IdentSyncWord=True) # what's that?!
>>> d.discover(SyncWordMatchList=[0x0c4e, 0xf432])
```

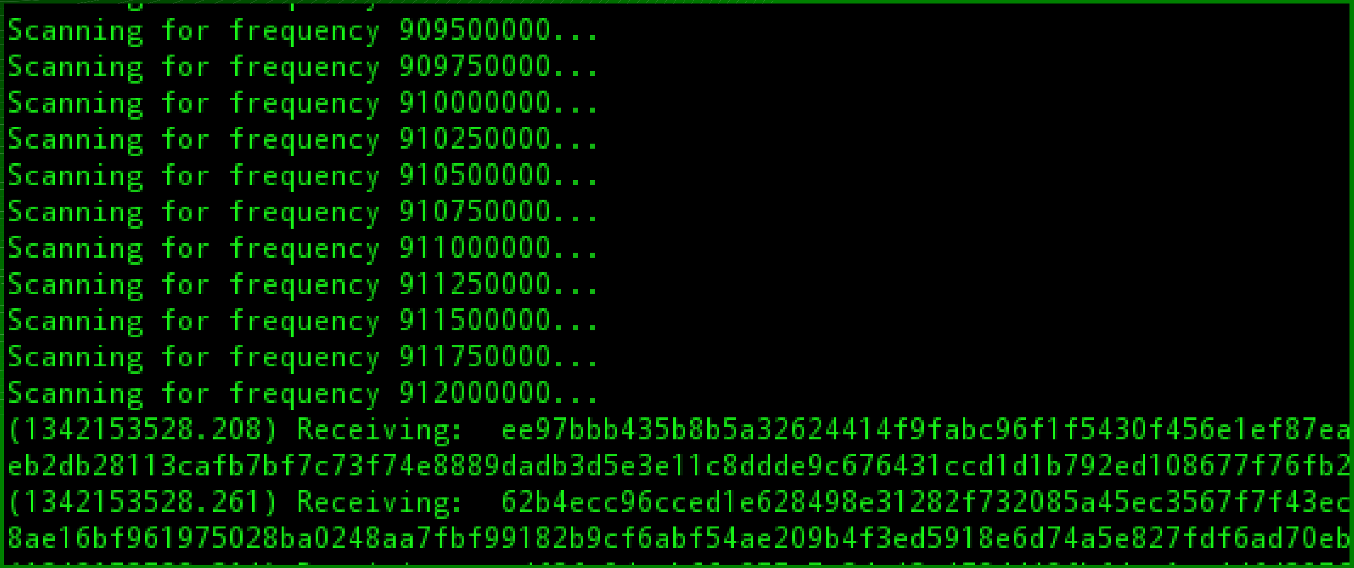
0xE6.2 – looking for trouble (kick in a door)

- frequency scanning (based on lowball)

```
>>> d.scan( basefreq, inc, count, delaysec, drate, lowball )
>>> d.scan(902e6, 250e3, 104, 2, 38400, 1)
```



```
In [1]: d.scan()
Scanning range:

Scanning for frequency 902000000...
Scanning for frequency 902250000...
Scanning for frequency 902500000...
Scanning for frequency 902750000...
Scanning for frequency 903000000...
Scanning for frequency 903250000...
Scanning for frequency 903500000...
Scanning for frequency 903750000...
Scanning for frequency 904000000...
Scanning for frequency 904250000...
Scanning for frequency 904500000...
Scanning for frequency 904750000...
Scanning for frequency 905000000...
Scanning for frequency 905250000...
```



```
Scanning for frequency 909500000...
Scanning for frequency 909750000...
Scanning for frequency 910000000...
Scanning for frequency 910250000...
Scanning for frequency 910500000...
Scanning for frequency 910750000...
Scanning for frequency 911000000...
Scanning for frequency 911250000...
Scanning for frequency 911500000...
Scanning for frequency 911750000...
Scanning for frequency 912000000...
(1342153528.208) Receiving:  ee97bbb435b8b5a32624414f9fabc96f1f5430f456e1ef87ea
eb2db28113cafb7bf7c73f74e8889dadb3d5e3e11c8ddde9c676431ccd1d1b792ed108677f76fb2
(1342153528.261) Receiving:  62b4ecc96cced1e628498e31282f732085a45ec3567f7f43ec
8ae16bf961975028ba0248aa7fbf99182b9cf6abf54ae209b4f3ed5918e6d74a5e827fdf6ad70eb
```

0x5080 – rfcat wicked coolness

- d._debug = 1 – dump debug messages as things happen
- d.debug() - print state infoz once a second
- d.discover() - listen for specific SYNCWORDS
- d.lowball() - disable most “filters” to see more packets
- d.lowballRestore() - restore the config before calling lowball()
- d.RFlisten() - simply dump data to screen
- d.RFcapture() - dump data to screen, return list of packets
- d.scan() - scan a configurable frequency range for “stuff”d
- d.specan() - spectum analysis (graphics thanks to Ubertooth folks)
- d.printRadioConfig() - print pretty config infoz

0x5090 – lowball and discover

- lowball mode stores current radio config

```
>>> d.lowball()        # drops most blocks to pkts (CARRIER)
>>> d.lowballRestore() # returns original config
>>> d.lowball(0)    # dumps all sorts of crap (SYNCM_NONE)
>>> d.lowball(1)    # default... same as no argument
```

- discover() uses lowball mode, adds value

```
d.discover(lowball, debug, length, IdentSyncWord, SyncWordMatchList)
>>> d.discover()    # enters lowball mode, dumps pkts
>>> d.discover(lowball=0)    # dumps way more pkts
>>> d.discover(IdentSyncWord=True)
>>> d.discover(SyncWordMatchList=[0xdead, 0xbeef])
```

0x5100 – one tool to rule them all...

- example RF attack lab setup:
  - dongle “Gina” running RfCat spectrum-analysis
  - dongle “Paul” running RfCat
  - IMME running RfSniff
  - (possibly an IMME's running SpecAn)
  - saleae logic analyzer for hacking of the wired variety
  - FunCube Dongle and quisk/qthid or other SDR
    - sssshhhhh... ignore the “other tools” or i'll have to change the slide title.
    - ok, so it's more like a goal than a title :)

rf attack form

- base freq:
- modulation:
- baud/bandwidth:
- deviation:
- channel hopping?
  - how many channels: channel spacing:
  - pattern and effective sync method? dwell period (ms):
- fixed-/variable-length packets: len/maxlen:
- “address”:
- sync word (if applicable):
- crc16 (y/n): does chip do correct style?
- fec (y/n): type (convolutional/reed-soloman/other):
- manchester encoding (y/n):
- data whitening? and 9bit pattern:
- more complete information: http://atlas.r4780y.com/resources/rf-recon-form.pdf

0xE7 – genie! oh genie!

configure the dongle / determine correct parameters: genie

- start RfCat
  - set Frequency to 315mhz
  - set Modulation to ASK_OOK
  - set SyncWord to AA00 and SyncMode to SYNCM_16_of_16
  - set Packet Length: 30
  - play around with baud rates... end up at 5200 baud
  - d.RFlisten()
  - try d.discover() instead of Rflisten

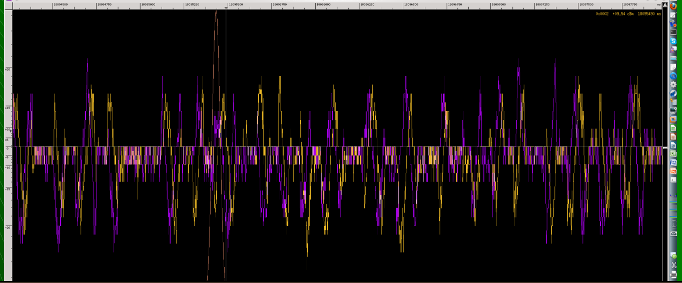
0x6000 – playing with medical devices

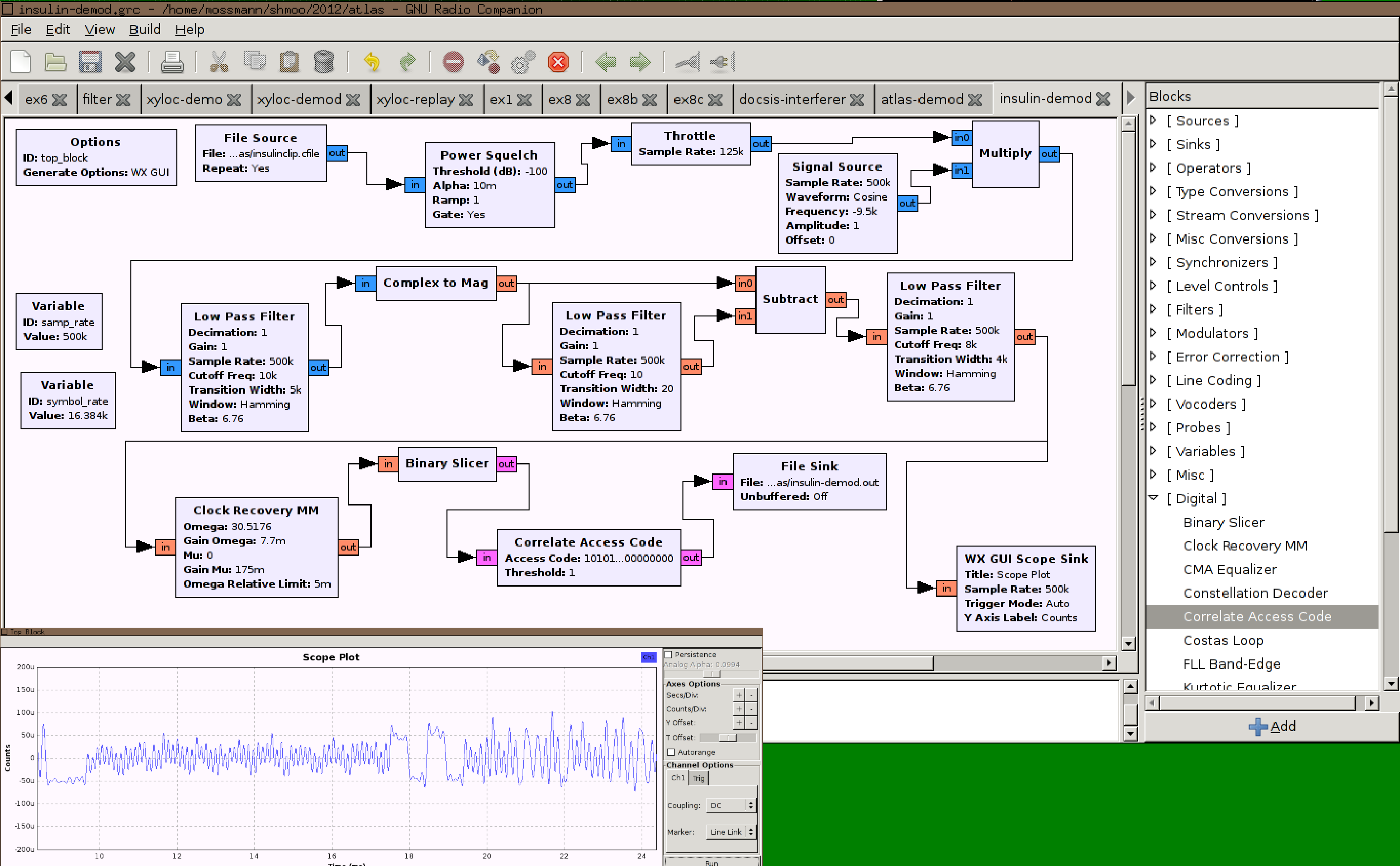
- CAUTION: MUCKING WITH THESE CAN KILL PEOPLE.
  - THIS FIRMWARE AND CLIENT NOT PROVIDED
- found frequency in the pdf manual from the Internet
  - what random diabetic cares what frequency his pump communicates with!? ok, who cares!
- modulation guessed based on spectrum analysis and trial/error
  - the wave form just **looks** like <blah> modulation!
- other characteristics discovered using a USRP and baudline (and some custom tools, thanks Mike Ossman!)

0x6010 – the discovery process

- glucometer was first captured using Spectrum Analyzer (IMME/hedyattack) to validate frequency range from the lay-documentation
- next a logic analyzer (saleae) used to tap debugging lines
- next, the transmission was captured using a USRP (thank you Mike Ossman for sending me your spare!)
- next, the “packet capture” was loaded into Baudline, and analysis performed to identify baudrate and modulation scheme, and get an idea of bits
- next, Mike Ossman did awesome-sauce, runnin the capture through GnuRadio Companion (the big picture on next slide)
- RF parameters confirmed through RF analysis, and real-life capture.

0x6011 – discovery reloaded





Options
ID: top_block
Generate Options: WX GUI

File Source
File: ...as/insulinclip.cfile
Repeat: Yes

Power Squelch
Threshold (dB): -100
Alpha: 10m
Ramp: 1
Gate: Yes

Throttle
Sample Rate: 125k

Signal Source
Sample Rate: 500k
Waveform: Cosine
Frequency: -9.5k
Amplitude: 1
Offset: 0

Multiply

Variable
ID: samp_rate
Value: 500k

Variable
ID: symbol_rate
Value: 16.384k

Complex to Mag

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 500k
Cutoff Freq: 10k
Transition Width: 5k
Window: Hamming
Beta: 6.76

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 500k
Cutoff Freq: 10
Transition Width: 20
Window: Hamming
Beta: 6.76

Subtract

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 500k
Cutoff Freq: 8k
Transition Width: 4k
Window: Hamming
Beta: 6.76

Binary Slicer

Clock Recovery MM
Omega: 30.5176
Gain Omega: 7.7m
Mu: 0
Gain Mu: 175m
Omega Relative Limit: 5m

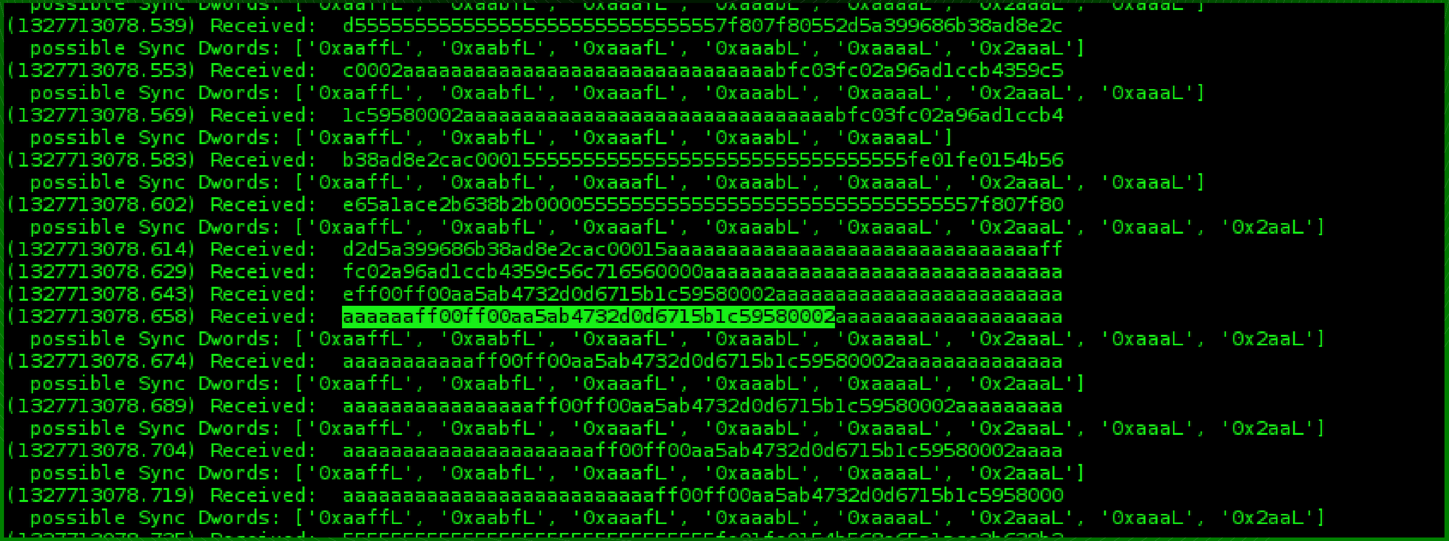
Correlate Access Code
Access Code: 10101...00000000
Threshold: 1

File Sink
File: ...as/insulin-demod.out
Unbuffered: Off

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 500k
Trigger Mode: Auto
Y Axis Label: Counts

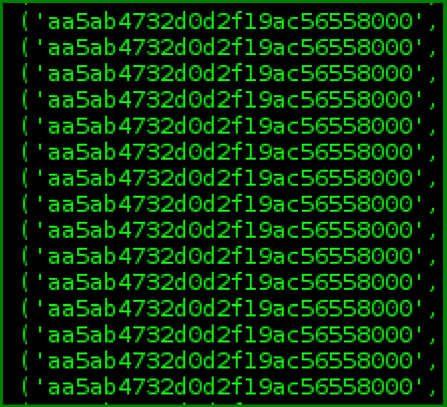
0x6020 – the immaculate reception

- punched in the RF parameters into a RFCAT dongle
  - created subclass of RFNIC (in python) for new RF config
- dropped into “discover” mode to ensure I had the modem right



```
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL']
(1327713078.539) Received:  d55555555555555555555555555555555557f807f80552d5a399686b38ad8e2c
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL']
(1327713078.553) Received:  c0002aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaabfc03fc02a96ad1ccb4359c5
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL']
(1327713078.569) Received:  1c59580002aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaabfc03fc02a96ad1ccb4
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL']
(1327713078.583) Received:  b38ad8e2cac0001555555555555555555555555555555555555fe01fe0154b56
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL']
(1327713078.602) Received:  e65a1ace2b638b2b0000555555555555555555555555555555555555557f807f80
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL', '0x2aaL']
(1327713078.614) Received:  d2d5a399686b38ad8e2cac00015aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaff
(1327713078.629) Received:  fc02a96ad1ccb4359c56c716560000aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
(1327713078.643) Received:  eff00ff00aa5ab4732d0d6715b1c59580002aaaaaaaaaaaaaaaaaaaaaaaaaaaa
(1327713078.658) Received:  aaaaaaff00ff00aa5ab4732d0d6715b1c59580002aaaaaaaaaaaaaaaaaaaaaaa
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL', '0x2aaL']
(1327713078.674) Received:  aaaaaaaaaaaff00ff00aa5ab4732d0d6715b1c59580002aaaaaaaaaaaaaaaaaa
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL']
(1327713078.689) Received:  aaaaaaaaaaaaaaaaff00ff00aa5ab4732d0d6715b1c59580002aaaaaaaaaaaaa
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL', '0x2aaL']
(1327713078.704) Received:  aaaaaaaaaaaaaaaaaaaaaaaaaff00ff00aa5ab4732d0d6715b1c59580002aaaa
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL']
(1327713078.719) Received:  aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaff00ff00aa5ab4732d0d6715b1c5958000
  possible Sync Dwords: ['0xaaffL', '0xaabfL', '0xaaafL', '0xaaabL', '0xaaaaL', '0x2aaaL', '0xaaaL', '0x2aaL']
```

- returned to normal NIC mode to receive real packets
- now need the pump to reverse the bi-dir protocol



```
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
('aa5ab4732d0d2f19ac56558000',
```

0xE8 – hop hop hopping along...

```
>>> d.getFHSSstate()
```

- import friend. decide who will be Sync Master.
- non-Master starts first:

```
>>> d.setFHSSstate(FHSS_STATE_DISCOVER)
```

- now the Sync Master:

```
>>> d.setFHSSstate(FHSS_STATE_SYNCINGMASTER)
```

- once sync'd:

```
>>> d.getMACdata()
>>> print d.reprMACdata()
```

0xE8.1 – FHSS xmit and recv

- now, one of you send (notice, different function)

```
>>> d.FHSSxmit('yo yo! wazgud!?')
```

- and the other of you receive:

```
>>> d.RFrecv()      # nothing special here
>>> d.RFlisten()    # same thing here
```

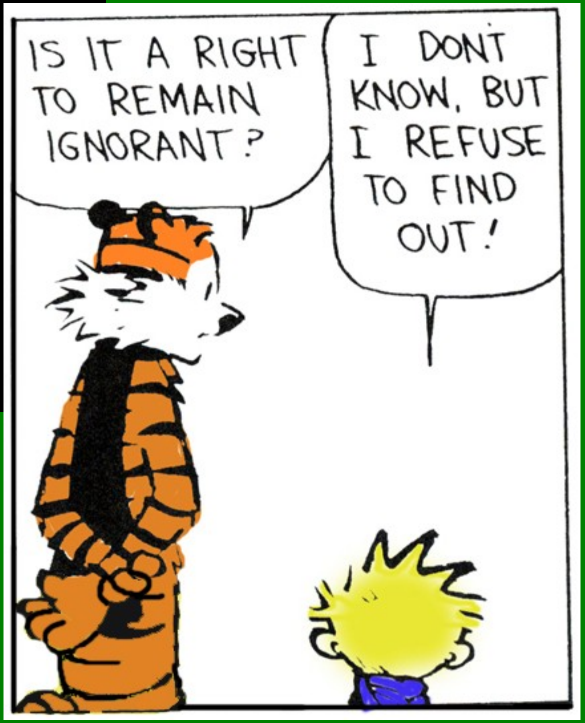
0x6100 – playing with a power meter

- CAUTION: MUCKING WITH POWER SYSTEMS WITHOUT APPROPRIATE AUTHORIZATION IS ILLEGAL, EVEN IF IT IS ON THE SIDE OF YOUR HOUSE!
- most power meters use their own proprietary “Neighborhood Area Network” (NAN), typically in the 900MHz range and sometimes 2.4GHz or licensed spectrum.
- to get the best reception over distance and gain tolerance to interference, all implement FHSS to take advantage of the Title 47: Part 15 power allowances
- many of the existing meters use the same cc1111 or cc1110 chips, or the cc1101 radio core
- this is the reason I'm here today

0x6110 – as sands through the hourglass

- power meter RF comms have long been “unavailable” for most security researchers
- **some vendors understand the benefits of security rigor by outside researchers**
  - others, however, do not.
- the gear used in my presentation was given to me by one who understands
  - for various reasons, they have asked to remain anonymous, however, their security team has a well founded approach to finding out “how their baby is ugly” I would like to give them credit for their commitment to the improved security of their products.

atlas, tell us what you really think

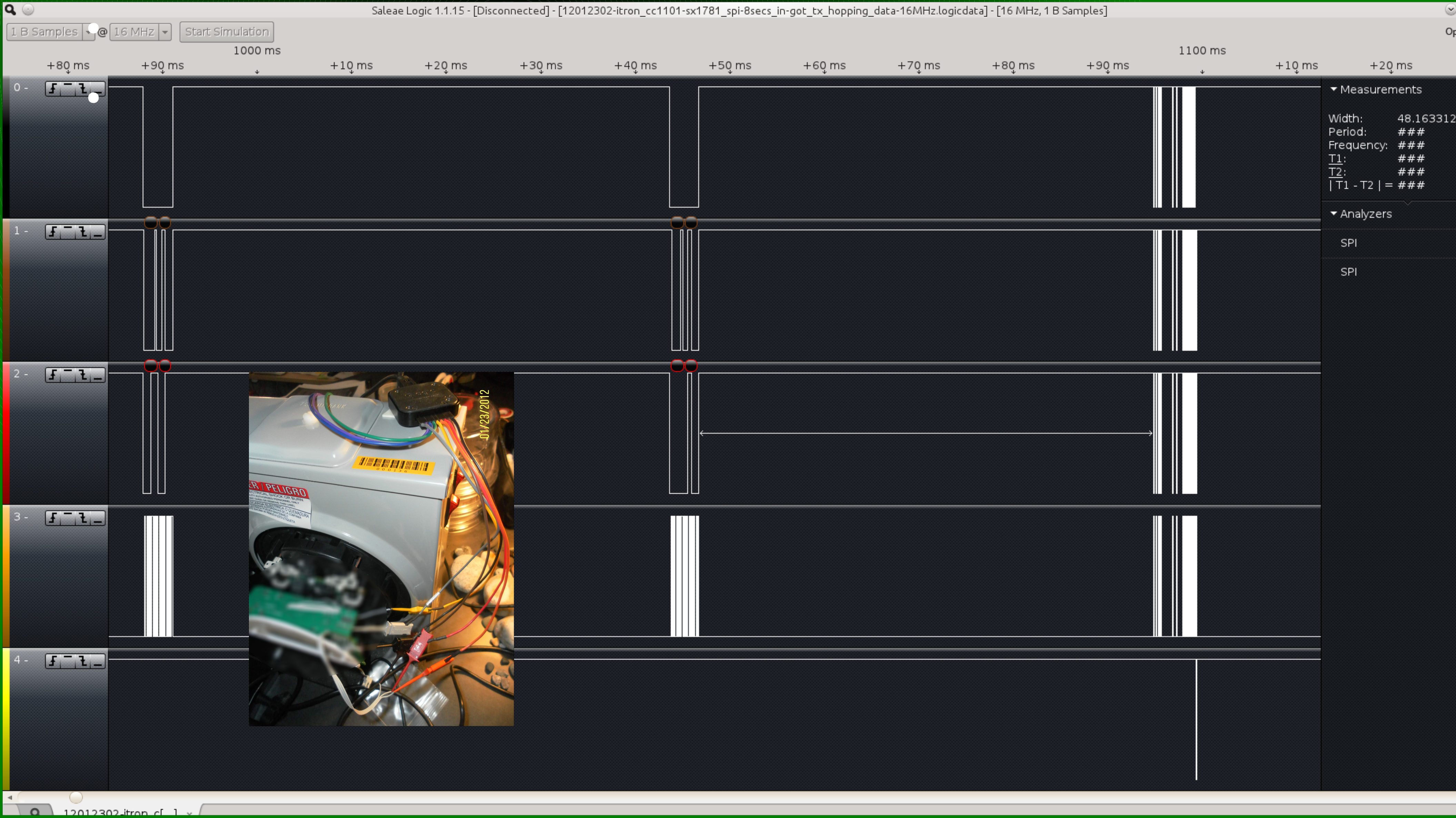

IS IT A RIGHT TO REMAIN IGNORANT?
I DON'T KNOW, BUT I REFUSE TO FIND OUT!

0x6120 – smart meter – the complication

- power meters are not so simple as glucometers
  - proprietary FHSS in a multiple-access topology
  - have to endure the RF abuse of the large metropolis
- complex mac sync/net-registration
- not easy to show with a single meter without a Master node.
- initial analysis was performed via my saleae LA:
- SpecAn code on IMME's and hedyattack dongles
  - good for identifying periods of scanning
- although the dongle can hop along with the meter, we won't be demoing synching with the meter today

0x6130 – the approach

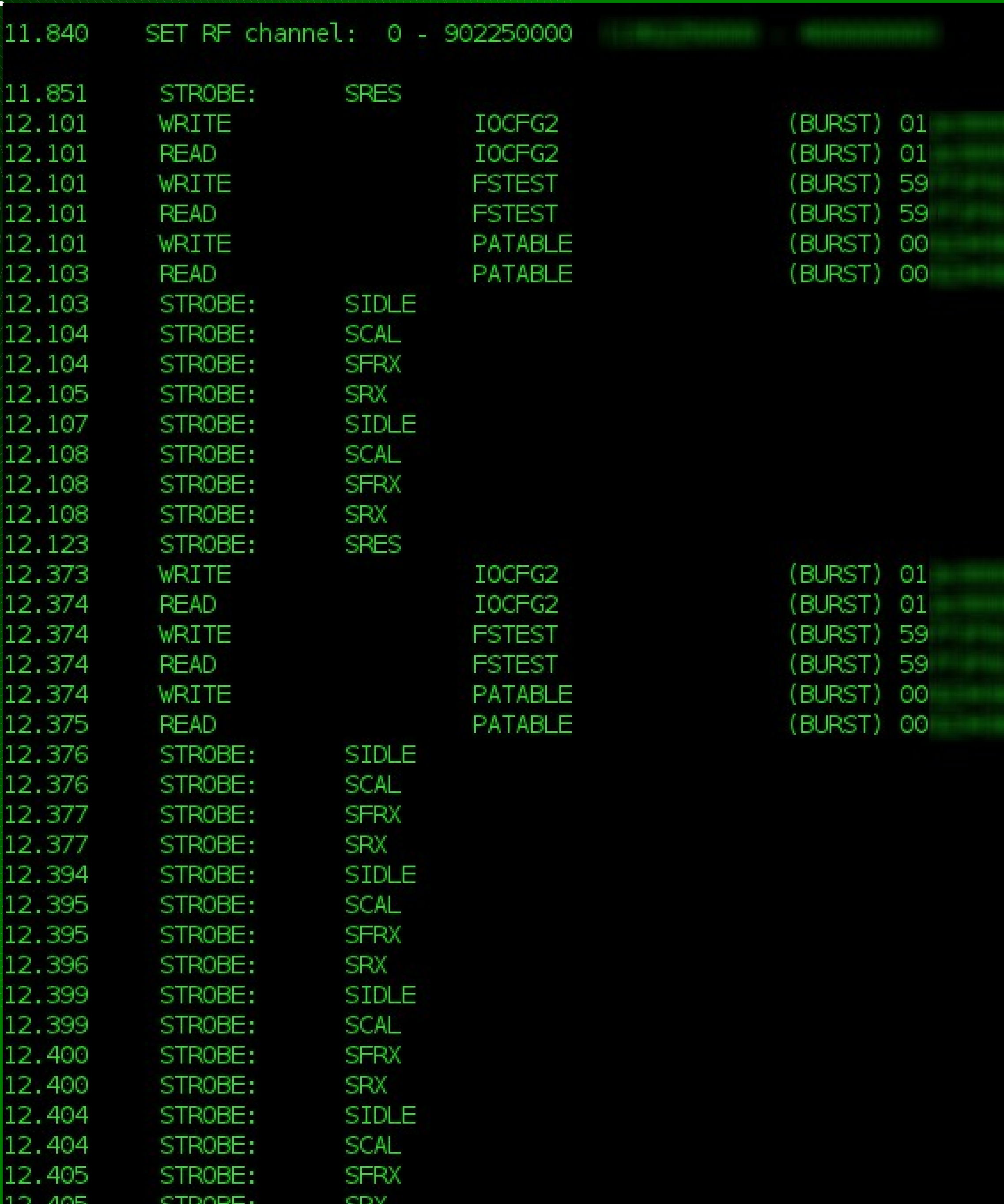
- determine the rf config and hopping pattern through SPI Bus sniffing (and my saleae again)


Saleae Logic 1.1.15 - [Disconnected] - [12012302-itron_cc1101-sx1781_spi-8secs_in-got_tx_hopping_data-16MHz.logicdata] - [16 MHz, 1 B Samples]

```
Width:      48.163312
Period:     ###
Frequency:  ###
T1:         ###
T2:         ###
| T1 - T2 | = ###
```

0x6135 – Logic Analyzer

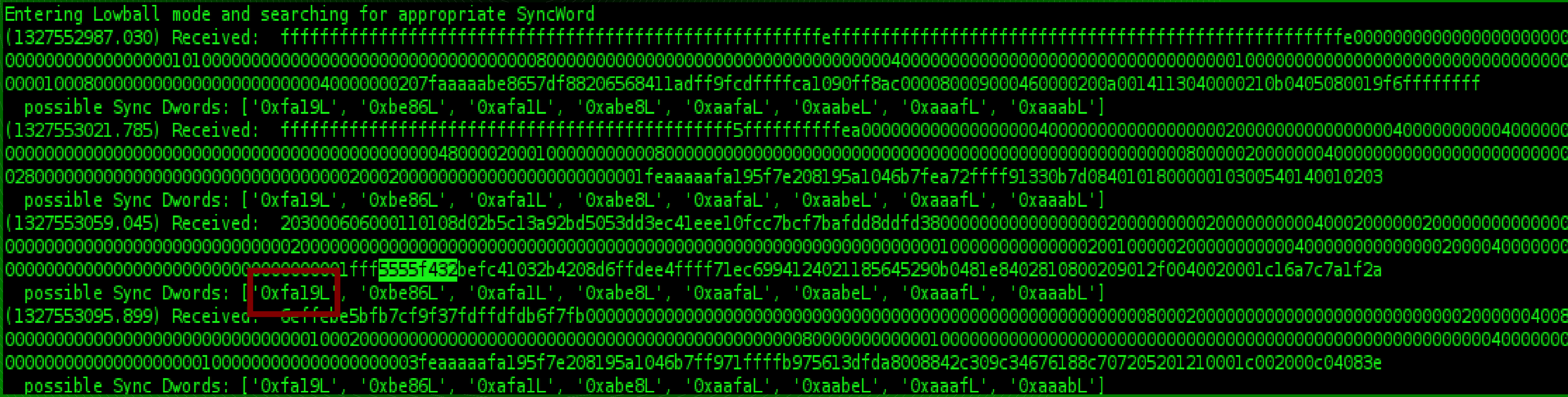
- decoding:
  - custom parser for the target radio--->>>



```
11.840    SET RF channel:  0 - 902250000  [redacted]

11.851     STROBE:      SRES
12.101     WRITE                 IOCFG2                (BURST) 01 [redacted]
12.101     READ                  IOCFG2                (BURST) 01 [redacted]
12.101     WRITE                 FSTEST                (BURST) 59 [redacted]
12.101     READ                  FSTEST                (BURST) 59 [redacted]
12.101     WRITE                 PATABLE               (BURST) 00 [redacted]
12.103     READ                  PATABLE               (BURST) 00 [redacted]
12.103     STROBE:      SIDLE
12.104     STROBE:      SCAL
12.104     STROBE:      SFRX
12.105     STROBE:      SRX
12.107     STROBE:      SIDLE
12.108     STROBE:      SCAL
12.108     STROBE:      SFRX
12.108     STROBE:      SRX
12.123     STROBE:      SRES
12.373     WRITE                 IOCFG2                (BURST) 01 [redacted]
12.374     READ                  IOCFG2                (BURST) 01 [redacted]
12.374     WRITE                 FSTEST                (BURST) 59 [redacted]
12.374     READ                  FSTEST                (BURST) 59 [redacted]
12.374     WRITE                 PATABLE               (BURST) 00 [redacted]
12.375     READ                  PATABLE               (BURST) 00 [redacted]
12.376     STROBE:      SIDLE
12.376     STROBE:      SCAL
12.377     STROBE:      SFRX
12.377     STROBE:      SRX
12.394     STROBE:      SIDLE
12.395     STROBE:      SCAL
12.395     STROBE:      SFRX
12.396     STROBE:      SRX
12.399     STROBE:      SIDLE
12.399     STROBE:      SCAL
12.400     STROBE:      SFRX
12.400     STROBE:      SRX
12.404     STROBE:      SIDLE
12.404     STROBE:      SCAL
12.405     STROBE:      SFRX
12.405     STROBE:      SRX
```

0x6140 – the approach (2)

- discover mode:
  - disables sync-word so radio sends unaligned bits



```
Entering Lowball mode and searching for appropriate SyncWord
(1327552987.030) Received:  ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffeffffffffffffffffffffffffffffffffffffffffffffffffffffffffe000000000000000000000
00000000000000000101000000000000000000000000000000000000000080000000000000000000000000000000000000040000000000000000000000000000000000001000000000000000000000000000000
00001000800000000000000000000000000040000000207faaaaabe8657df882065684lladff9fcdffffca1090ff8ac00008000900046000020 0a0014113040000210b0405080019f6ffffffff
  possible Sync Dwords: ['0xfa19L', '0xbe86L', '0xafa1L', '0xabe8L', '0xaafaL', '0xaabeL', '0xaaafL', '0xaaabL']
(1327553021.785) Received:  fffffffffffffffffffffffffffffffffffffffffffffffffff5ffffffffffea0000000000000000000040000000000000000000020000000000000000000040000000000004000000
00000000000000000000000000000000000000000000048000020001000000000000080000000000000000000000000000000000000000000000000000000080000020000000400000000000000000000000000
0280000000000000000000000000000000000000020002000000000000000000000000001feaaaaafa195f7e208195a1046b7fea72ffff91330b7d08401018000001030054014001020 3
  possible Sync Dwords: ['0xfa19L', '0xbe86L', '0xafa1L', '0xabe8L', '0xaafaL', '0xaabeL', '0xaaafL', '0xaaabL']
(1327553059.045) Received:  203000606000110108d02b5c13a92bd5053dd3ec41eee10fcc7bcf7bafdd8ddfd38000000000000000000020000000000020000000000004000200000020000000000000
00000000000000000000000000002000000000000000000000000000000000000000000000000000000000000000010000000000000000200100000200000000000000400000000000000002000040000000
00000000000000000000000000000000001fff5555f432befc41032b4208d6ffdee4ffff71ec699412402118564529 0b0481e840281080020 9012f0040020001c16a7c7a1f2a
  possible Sync Dwords: ['0xfa19L', '0xbe86L', '0xafa1L', '0xabe8L', '0xaafaL', '0xaabeL', '0xaaafL', '0xaaabL']
(1327553095.899) Received:  0effebe5bfb7cf9f37fdffdfdb6f7fb0000000000000000000000000000000000000000000000000000080002000000000000000000000000000000000200000004008
00000000000000000000000000000001000200000000000000000000000000000000000000000000008000000000000001000000000000000000000000000000000000000000000000000000000000040000000
00000000000000000001000000000000000000000003feaaaaafa195f7e208195a1046b7ff971ffffb975613dfda8008842c309c34676188c70720520121000 1c002000c04083e
  possible Sync Dwords: ['0xfa19L', '0xbe86L', '0xafa1L', '0xabe8L', '0xaafaL', '0xaabeL', '0xaaafL', '0xaaabL']
```

  - algorithm looks for preamble (0xaa or 0x55)
  - then determines possible dwords
- ummm... but that's not any bit-derivation of the sync word(s) I expect. wut? I am confident those are coming from the meter
  - intro: Bit Inversion (see highlighted hex)

0x6145 – new developments

- vendors filed numerous patents with hopping pattern calculations, communications parameters, etc...
  - WIN!
  - plenty of work to be done! jump right in!
    - http://www.patentstorm.us/patents/7064679/fulltext.html
    - http://www.patentstorm.us/patents/7962101/fulltext.html
    - http://www.patentstorm.us/applications/20080204272/fulltext.html
    - http://www.patentstorm.us/applications/20080238716/fulltext.html

“Abuse is no argument”

- Nevil Maskelyne

0x6150 - conclusions

- rfcat roxors
- rfcat is a **foundation** for your attack tool
  - way more than just a tool in itself
- we are responsible for ensuring our devices use appropriate security. **do not** simply expect someone else to do it. the first med-device death could be your best friend.

References

- http://rfcat.googlecode.com
- http://en.wikipedia.org/wiki/Part_15_(FCC_rules)
- http://en.wikipedia.org/wiki/ISM_band
- http://www.ti.com/lit/ds/swrs033g/swrs033g.pdf - “the” manual
- http://edge.rit.edu/content/P11207/public/CC1111_USB_HW_User_s_Guide.pdf
- http://www.ti.com/litv/pdf/swru082b
- http://www.ti.com/product/cc1111f32#technicaldocuments
- http://www.ti.com/lit/an/swra077/swra077.pdf
- http://www.newscientist.com/article/mg21228440.700-dotdashdiss-the-gentleman-hackers-1903-lulz.html
- http://saleae.com/
- http://zone.ni.com/devzone/cda/epd/p/id/5150 - FSK details (worthwhile!)
- http://www.radagast.org/~dplatt/hamradio/FARS_presentation_on_modulation.pdf
  - very good detailed discussion on deviation/modulation
- http://en.wikipedia.org/wiki/Frequency_modulation
- http://en.wikipedia.org/wiki/Minimum-shift_keying

0xgreetz

- power hardware folk who play nice with security researchers
- cutaway and q (awesome hedyattackers)
- gerard van den bosch
- travis and mossman
- sk0d0 and the four J's
- invisigoth and kenshoto
- jewel, bug, ringwraith, diva
- Jesus Christ