What IQ Can Do For You!

A tutorial of

Quadrature Amplitude/Phase Modulation (QAM,or QPSK) and its implementation in Software Defined Radio (SDR)

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The Timeline of **S**oftware **D**efined **R**adio

1984- The first mention of the term “Software Radio” can be traced back to a newsletter published by E-Systems, in Garland, Texas. In this letter they were referring to a prototype receiver.

1991- The first military program to require that physical layer components be implemented in software was a DARPA project named SPEAKeasy. The purpose of this project was to create a radio capable of working over a wide frequency range, and support numerous protocols.

The Timeline of Software Defined Radio

1992- Dr. Joseph Mitola presents “Software Radio: Survey, Critical Analysis and Future Directions”. Solidifying his place as the grandfather of Software Radio despite the previous use of the term.

1997- Creation of JTRS (Joint Tactical Radio System). This project was eventually scrapped by the DoD (Department of Defense) in 2011.

2001- GNU Radio “open-source framework for the development of SDR applications within a PC environment.” A development tool set that can be ran on any x86 (32-Bit) system.

The Timeline of Software Defined Radio

2004- First FCC approved SDR Developed by Vanu Inc.

2009- First commercial single chip RF front end developed by Lime Microsystems (LMS6002). Another RFIC was developed by Motorola years before, but was not widely released.

2010's- RTL2832U Chipsets used in DVB-T tuners are discovered to have raw I/Q data on the RTL2832U chipset could be accessed directly. Allowing for very cheap SDR receivers to be used. (Under $30).

Frequency capability is approximately 25MHz-1750MHz, with no gaps within that range. Expansion to HF, all the way down to 100kHz, is available with the Ham It Up upconverter

The NOO Mini 2 USB Receiver

- $25 for 24Mhz to 1.7 Ghz with small antenna..
  - Add PL259 adapter and others (BNC, TNC,)
- $55 for HF upconverter to 125 Mhz.
- Kits with cases and cables $125
- Computer programs are free (SDR# and HDSDR are popular)
  - Frequency and waterfall display
  - IF filter and display, Squelch, Noise limiter, Audio displays
- Can be used to test a transmitter
- Demonstration of
  - FM (Narrow and Wide),
  - CW
  - USB
- Use Raw I/Q to do anything else
  - PK31, Slow scan, QAM… Whatever the FCC allows.
  - Future seminars on

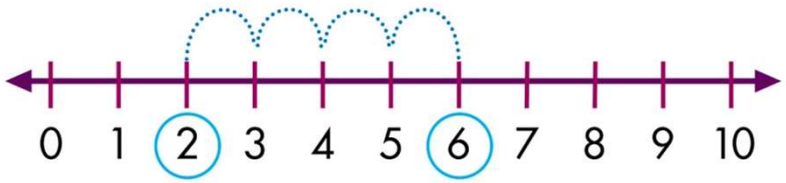
Required Background

- Addition
  - Example 1 + 1.0 = 2.0
- Multiplication
  - Example 3.14 x 2 = 6.28
- Follow a step by step procedure (program)
- *Somewhat tedious for us but*
  - *Software in computers let us do these 3 things very fast.*
  - *Hundred Million times per sec.*

Concept: 1(One) Number Spaces

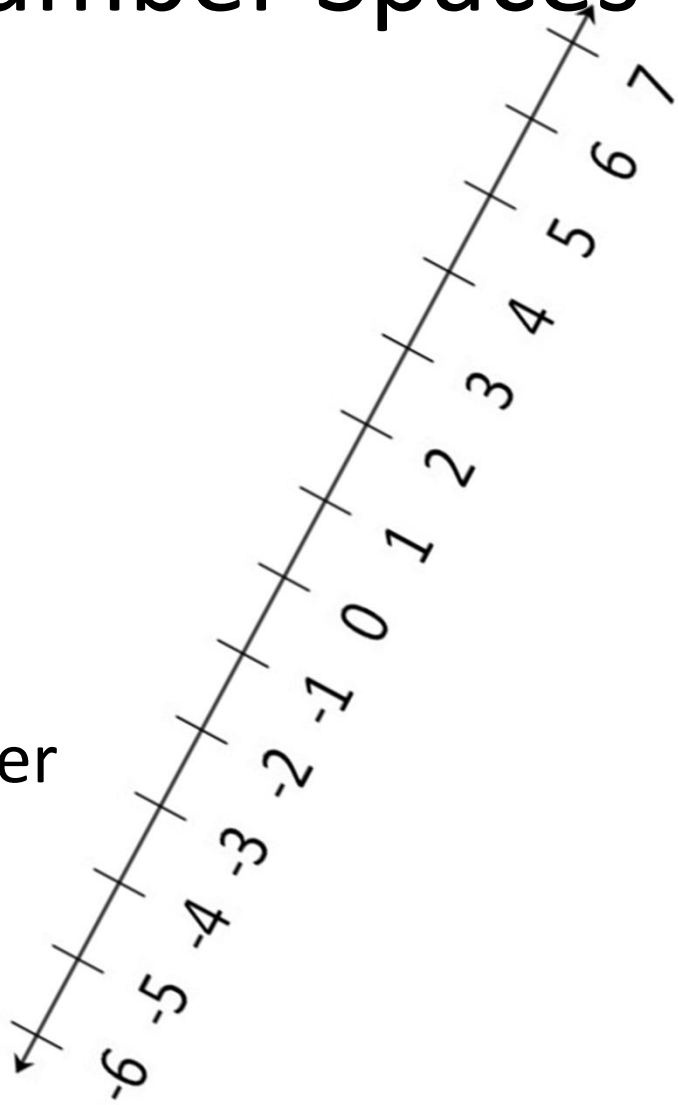
- Number Line

$$2 + 4 = 6$$



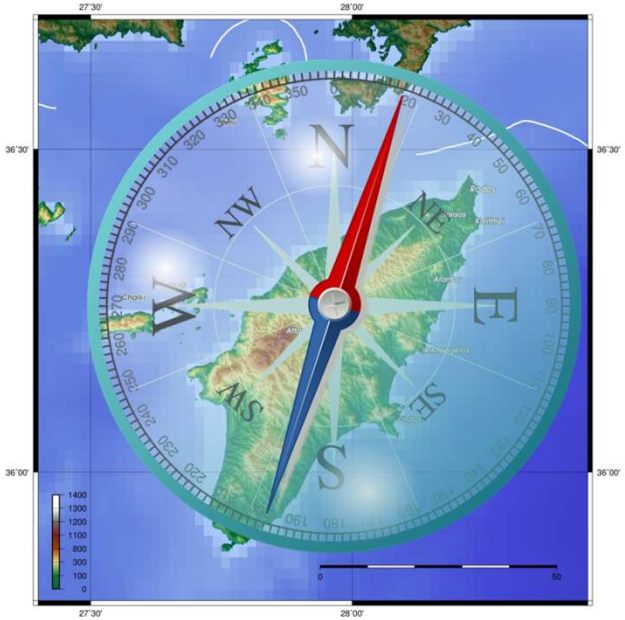
- Angle doesn't matter

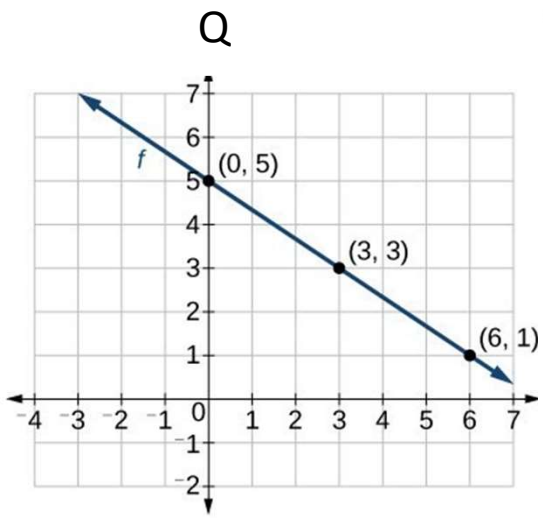
  Only points on the line matter

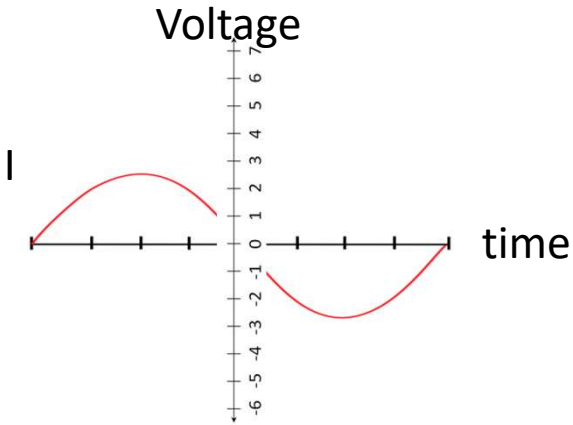


2 Number Spaces

- Map (North and East)
  - West is minus East,
  - South is Minus North
- Graph
  - Let's use
    - **I for East**
    - **Q for North**
- Radio signals
  - Voltage
  - Time



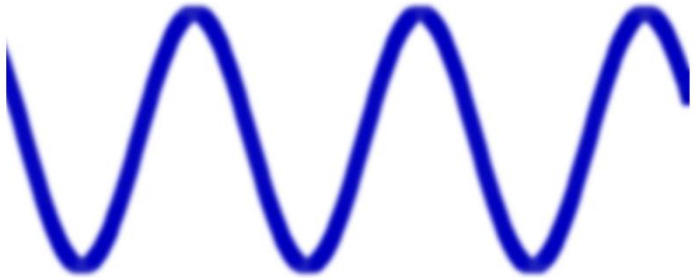




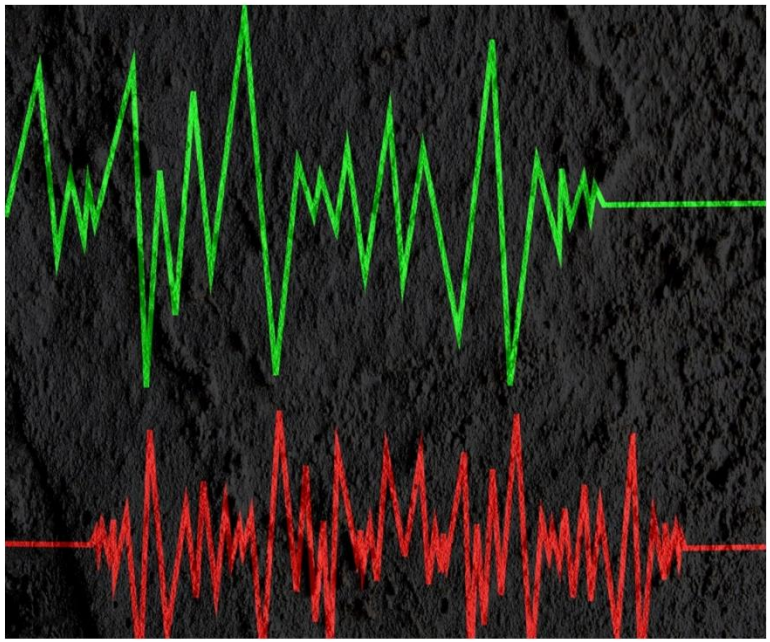
2 Number Space Defines IQ Radios
I and Q are the signals

- For example
  - Stereo Left (I) and Right (Q)

- Left



- Right



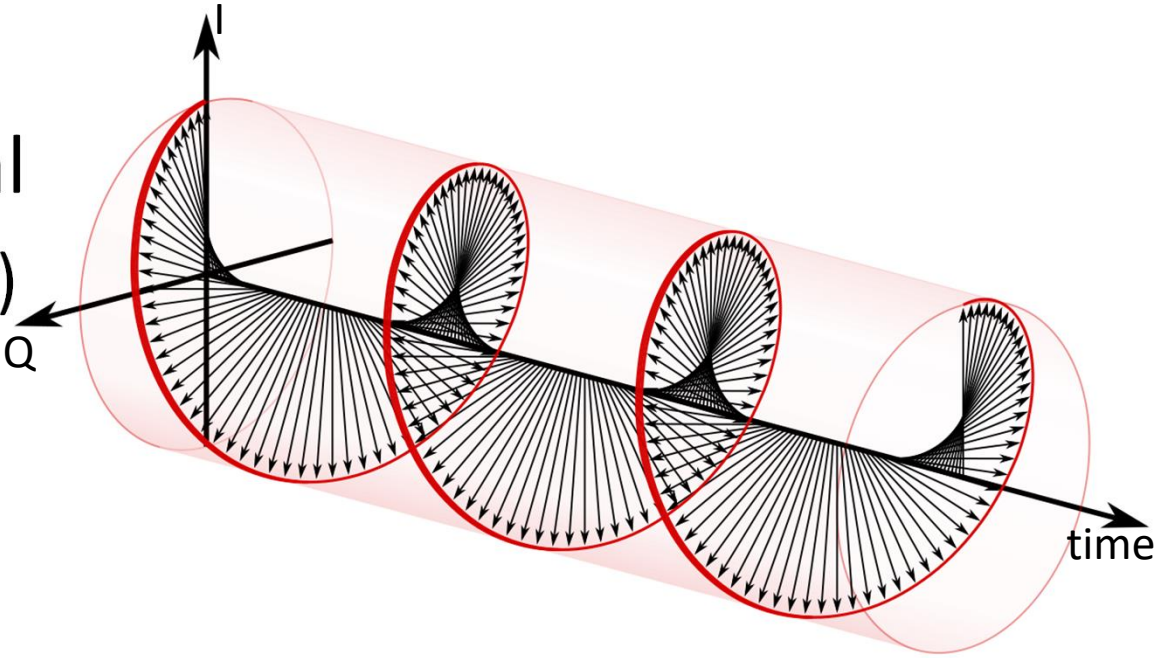
Other examples

- Single Sideband (SSB)
  - Audio (I)
  - Phase shifted audio (Q)
- Vara modulation
  - Every other bit (I)
  - The other bit (Q)
- FM .. I and Q rotate around a circle
- WiFi – OFDM, I and Q on 512 carriers

3 Number Spaces

- Earth
  - (Latitude, Longitude, Altitude)

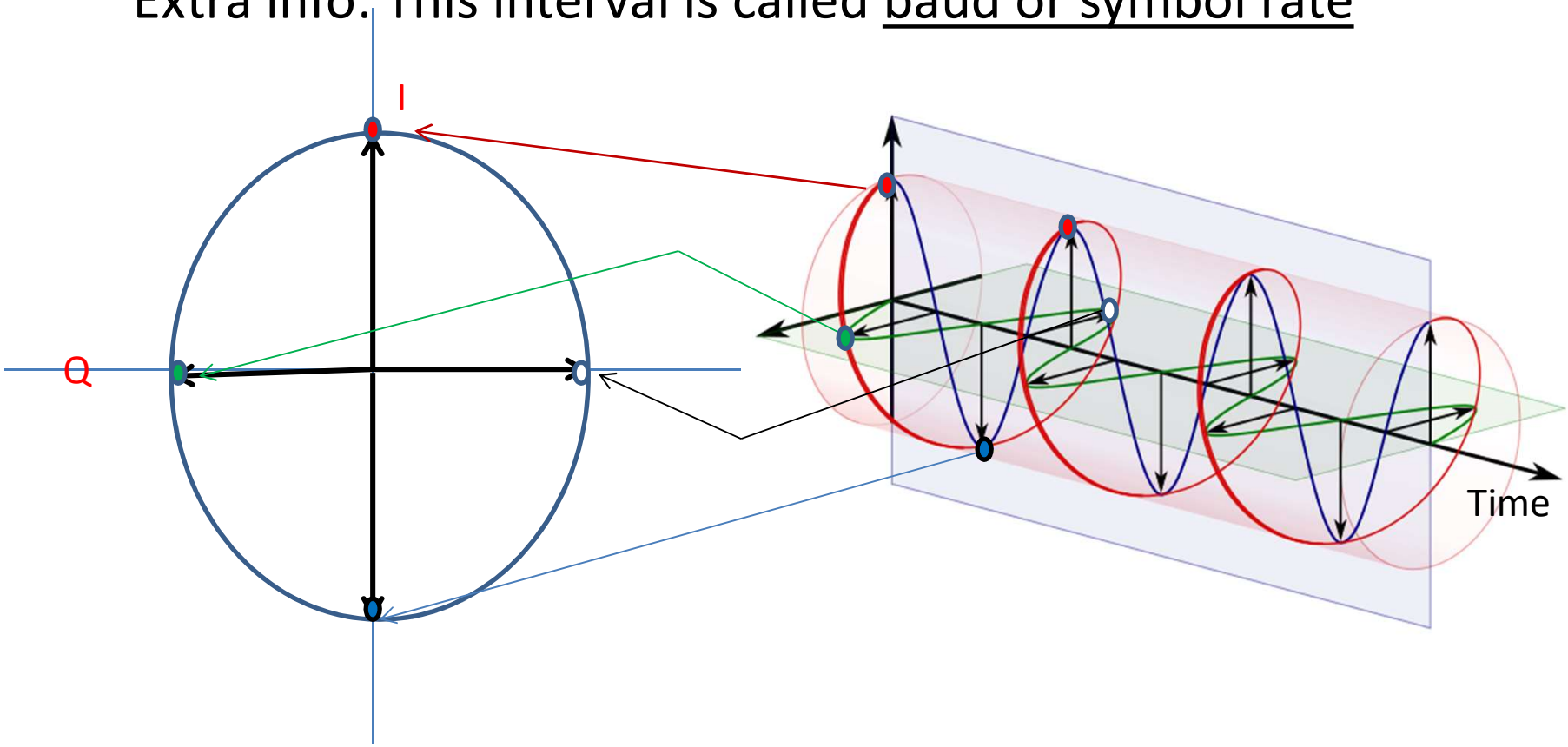
- Radio Signal
  - (I,Q, time)



Let's simplify from 3 to 2 numbers

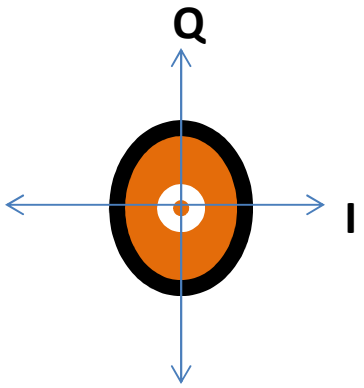
Only look at I and Q at fixed intervals of time, like only where the arrows are. See the red dots.

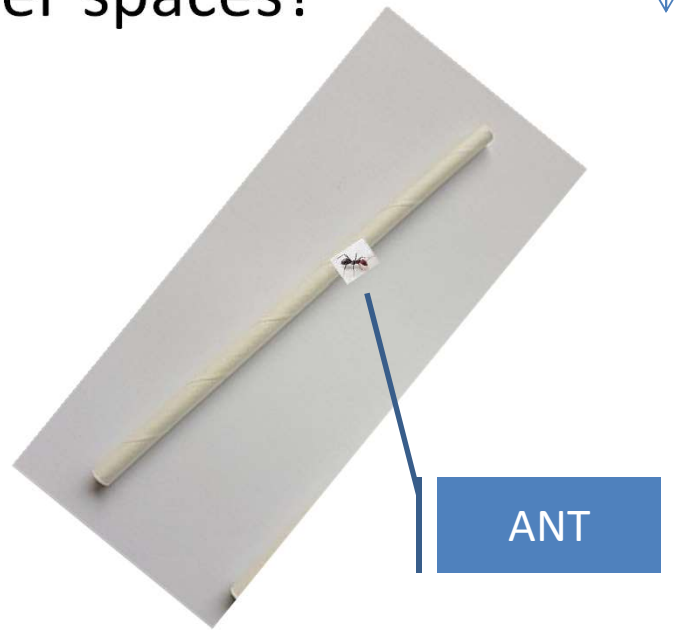
Extra info: This interval is called <u>baud or symbol rate</u>

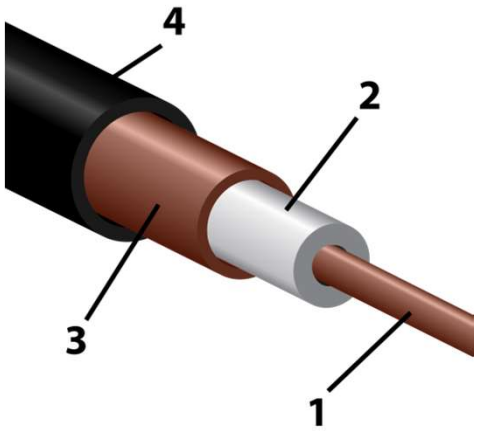


Quiz: Drinking Straw / Coax

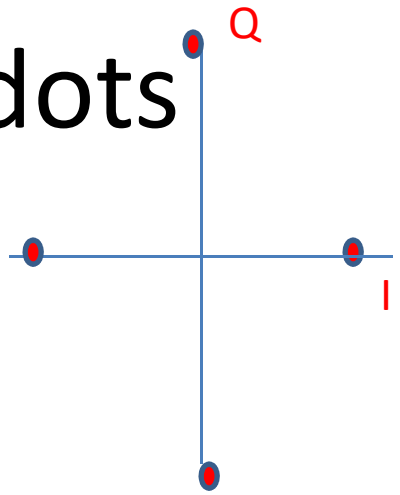
- Question: Are these
  - 1 number spaces
  - 2 number spaces
  - 3 number spaces?







Let's make some I Q dots

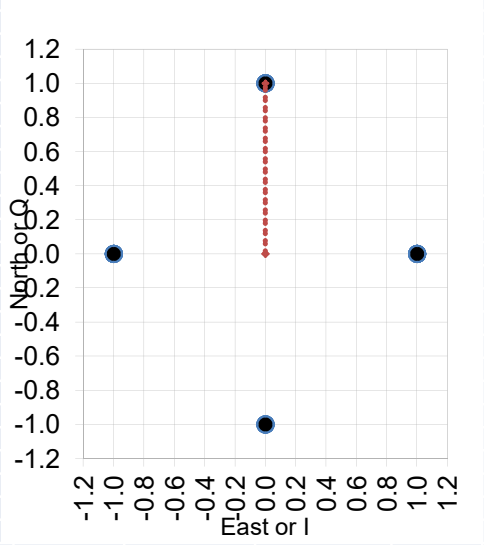


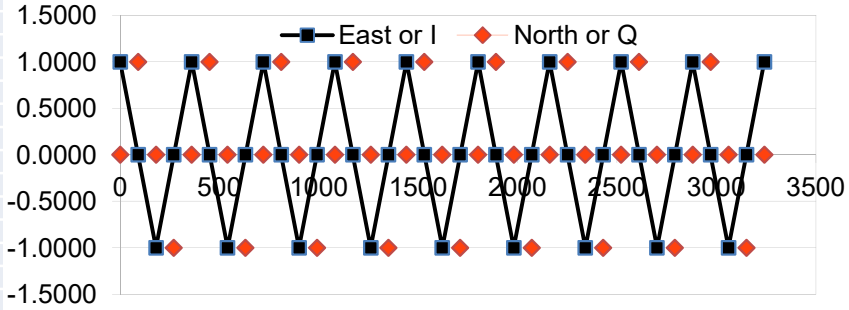
- Step 0. Start with a dot at
  - I = 1 Q = 0
- Step 1. Move it by swapping I and Q
  - I = 0 Q = 1
  - And change the sign of I (in this step I is 0, -0 is 0)
- Do this three more times
  - Step 2. I = 1 Q= 0 after swap but I becomes -1 so
  - I = -1 Q =0
  - Step 3. I = 0 Q= -1
  - Step 4. I= -1 Q= 0 after swap but I becomes +1 so
  - I= +1 Q= 0
- Note that we are back in the same place
- If we repeat, we will go around and around.

Spreadsheet version

Enter an angle in Deg	R	X		1<-Length	General step Formula			Square formula		
90	0.0000	1.0000	rotation vector= (R,X)							
Angle	East or I	North or Q			I	Q				
0	1.0000	0.0000	initial (I,Q)		Eo	No	Step 0	Io	Qo	
90	0.00	1.00	Step1		Eo R - No X	Eo X + No R	Step 1	Change sign of Qo	Io	
180	-1.0000	0.0000	Step2					East <= - North	North <= East	
270	0.0000	-1.0000	Step3							
360	1.0000	0.0000	Step4							
450	0.0000	1.0000	Step5							
540	-1.0000	0.0000	Step6							
630	0.0000	-1.0000	Step7							
720	1.0000	0.0000	Step8							
810	0.0000	1.0000	Step9							
900	-1.0000	0.0000	Step10							
990	0.0000	-1.0000	Step11							
1080	1.0000	0.0000	Step12							
1170	0.0000	1.0000	Step13							
1260	-1.0000	0.0000	Step14							
1350	0.0000	-1.0000	Step15							
1440	1.0000	0.0000	Step16							
1530	0.0000	1.0000	Step17							
1620	-1.0000	0.0000	Step18							
1710	0.0000	-1.0000	Step19							
1800	1.0000	0.0000	Step20							
1890	0.0000	1.0000	Step21							
1980	-1.0000	0.0000	Step22							
2070	0.0000	-1.0000	Step23							
2160	1.0000	0.0000	Step24							
2250	0.0000	1.0000	Step25							
2340	-1.0000	0.0000	Step26							
2430	0.0000	-1.0000	Step27							
2520	1.0000	0.0000	Step28							
2610	0.0000	1.0000	Step29							
2700	-1.0000	0.0000	Step30							
2790	0.0000	-1.0000	Step31							
2880	1.0000	0.0000	Step32							
2970	0.0000	1.0000	Step33							
3060	-1.0000	0.0000	Step34							
3150	0.0000	-1.0000	Step35							
3240	1.0000	0.0000	Step36							

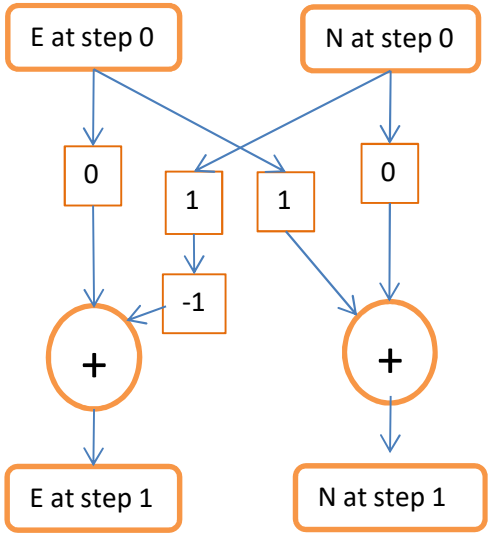
Angle	Figure	Sides(N)
120	Triangle	3
90	Square	4
72	Pentagon	5
60	Hexagon	6
51.42857	Septagon	7
40	Nonagon	9
45	Octagon	8
36	Decagon	10
30	Dodecagon	12
15	N-gon	24
10	N-gon	36
5	N-gon	72
1	N-gon	360



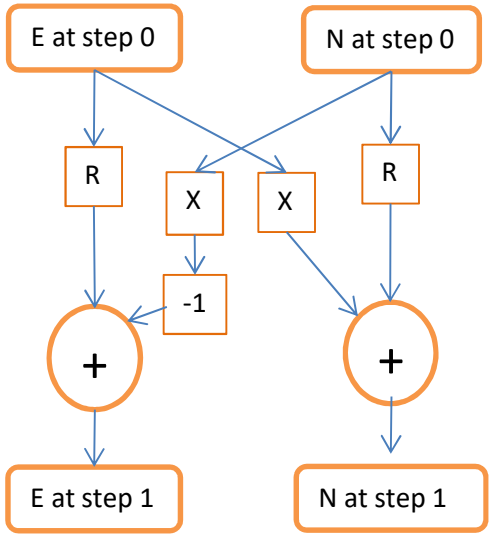


General Step Procedure for I,Q Carrier Generation

Simple case we just did

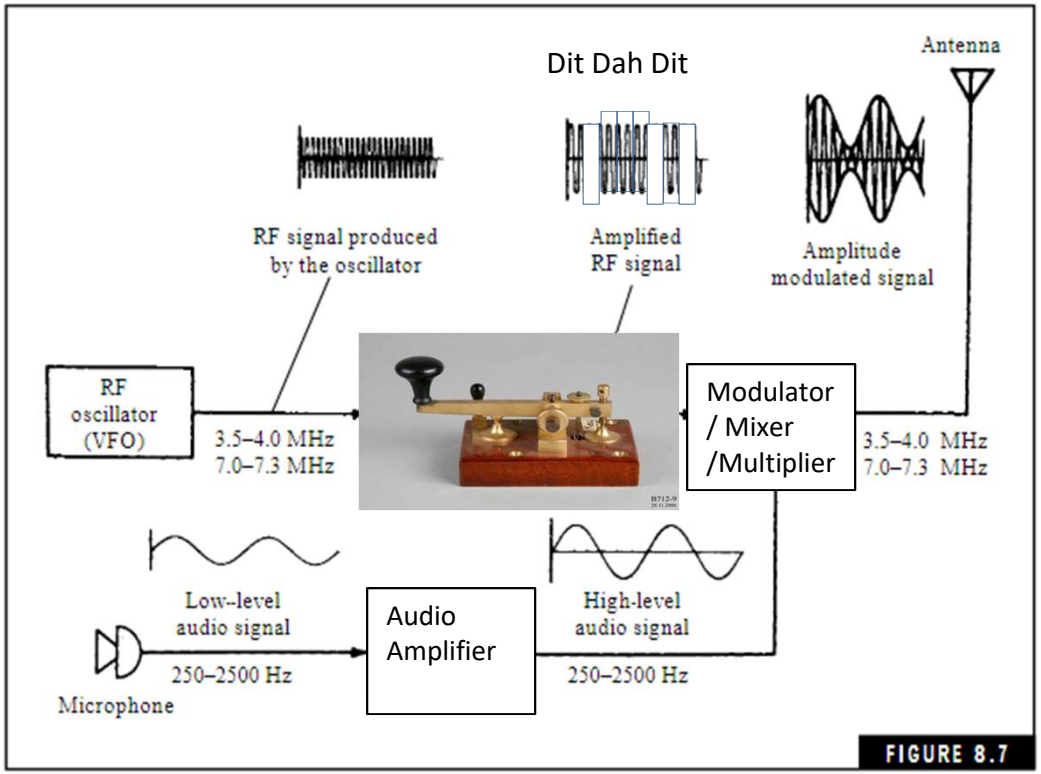


General case
R and X are the position after the first step



The Tale of 2 AM Radios

- One Am/CW radio



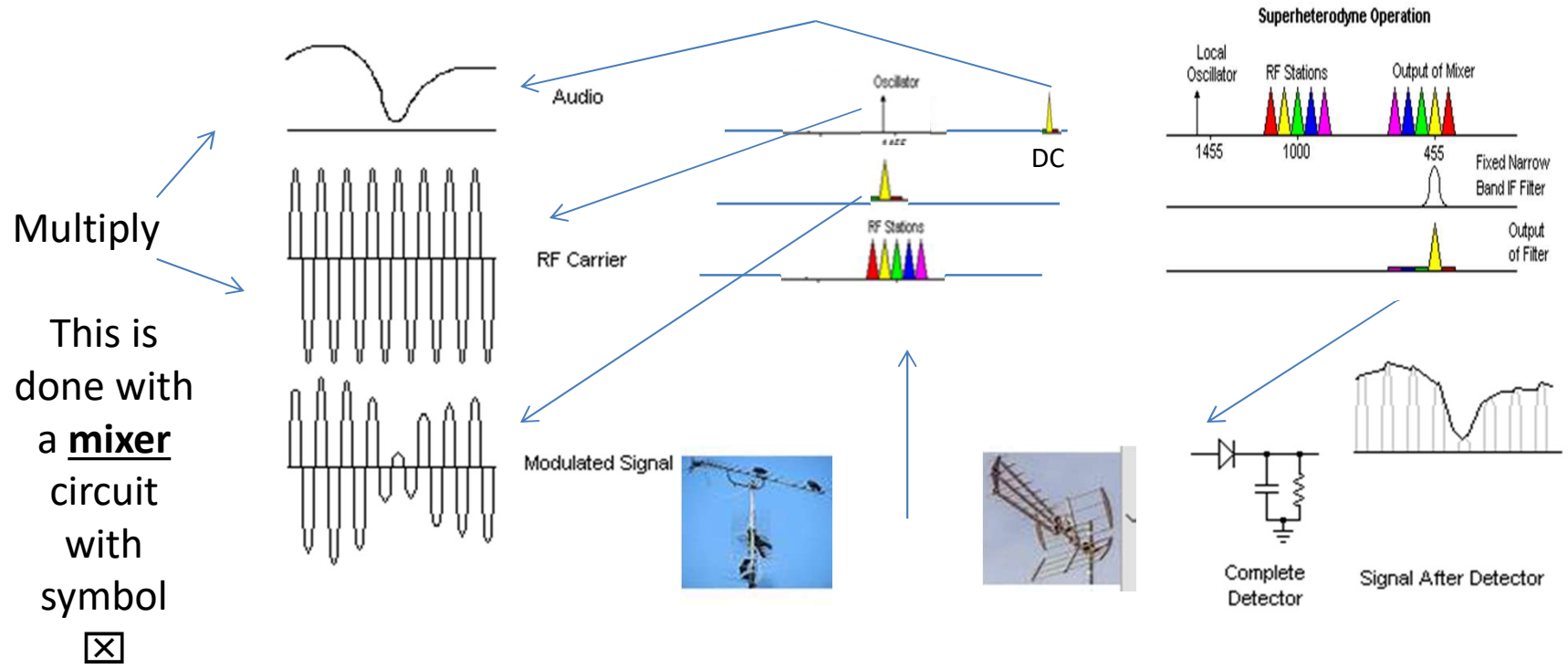
Block diagram for an amplitude modulated transmitter for the 75-and 40-meter HF bands.

- QAM /QPSK
  - is 2 AM radios
- But with a twist

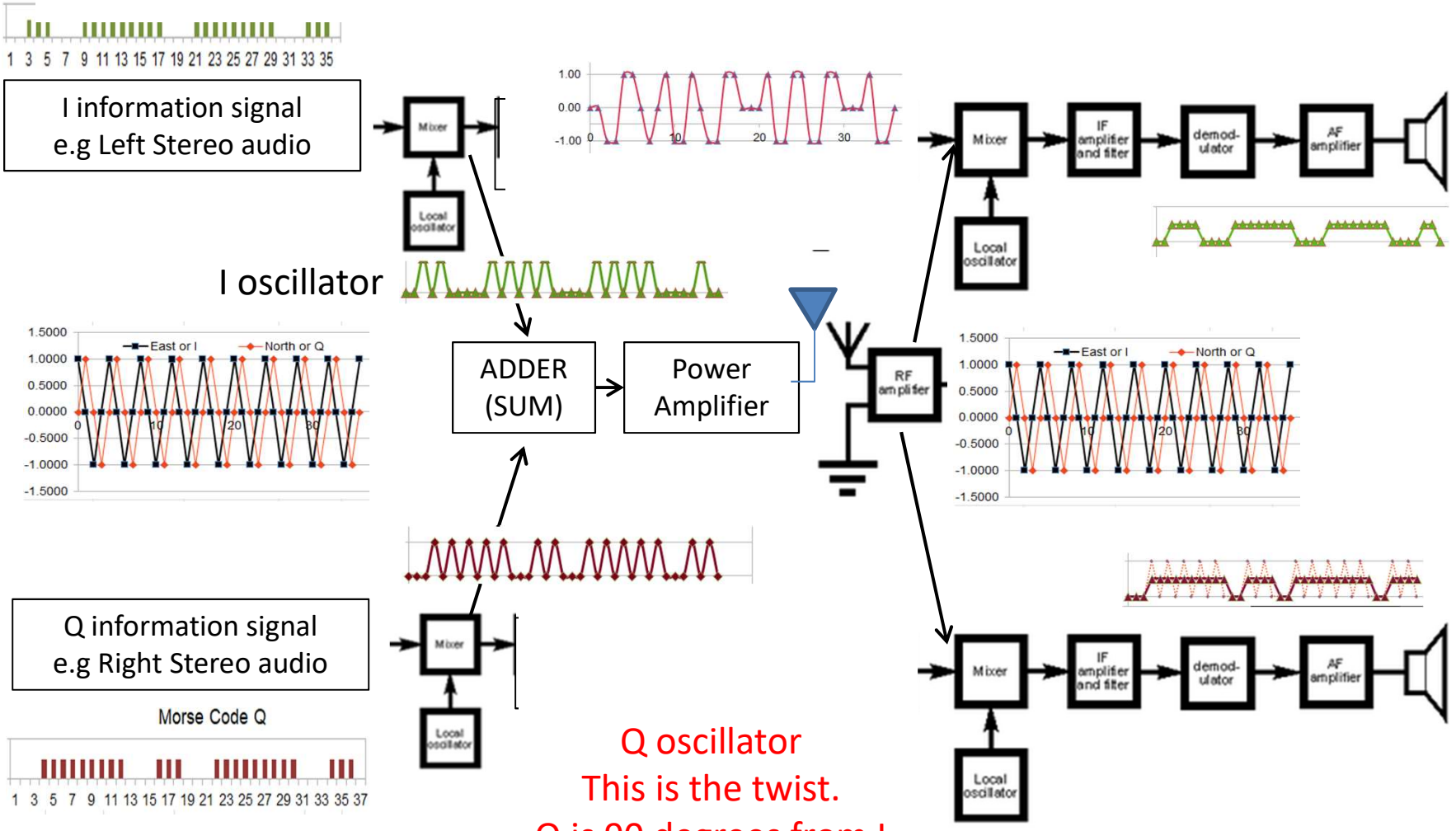
- https://www.qsl.net/sp9hzx/img/The%20Beginner%27s%20Handbook%20of%20Amateur%20Radio.pdf

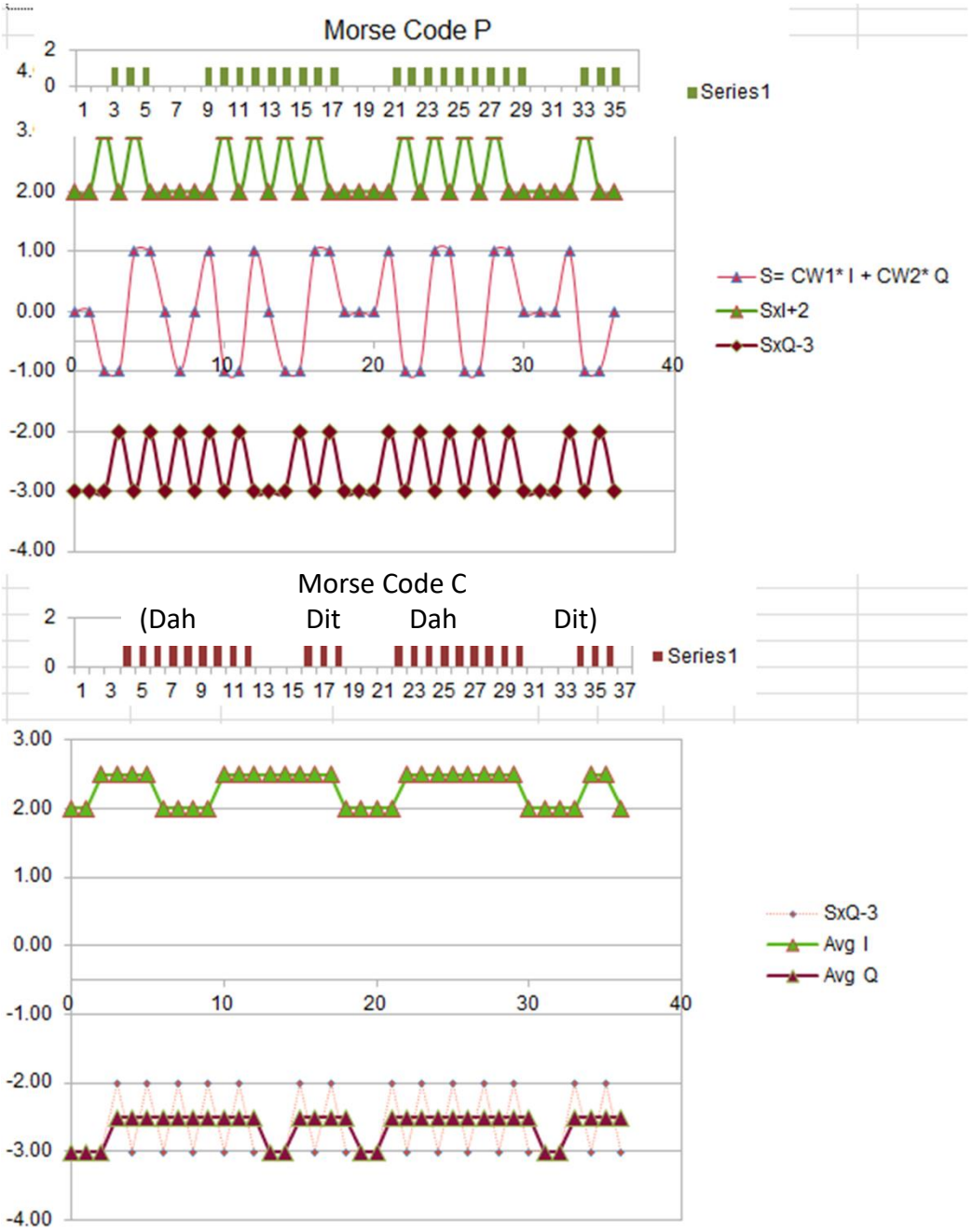
AM radio - review

- https://www.electronixandmore.com/resources/amradio/
- Transmitter On Air Spectrum Receiver



QAM/QPSK Block Diagram



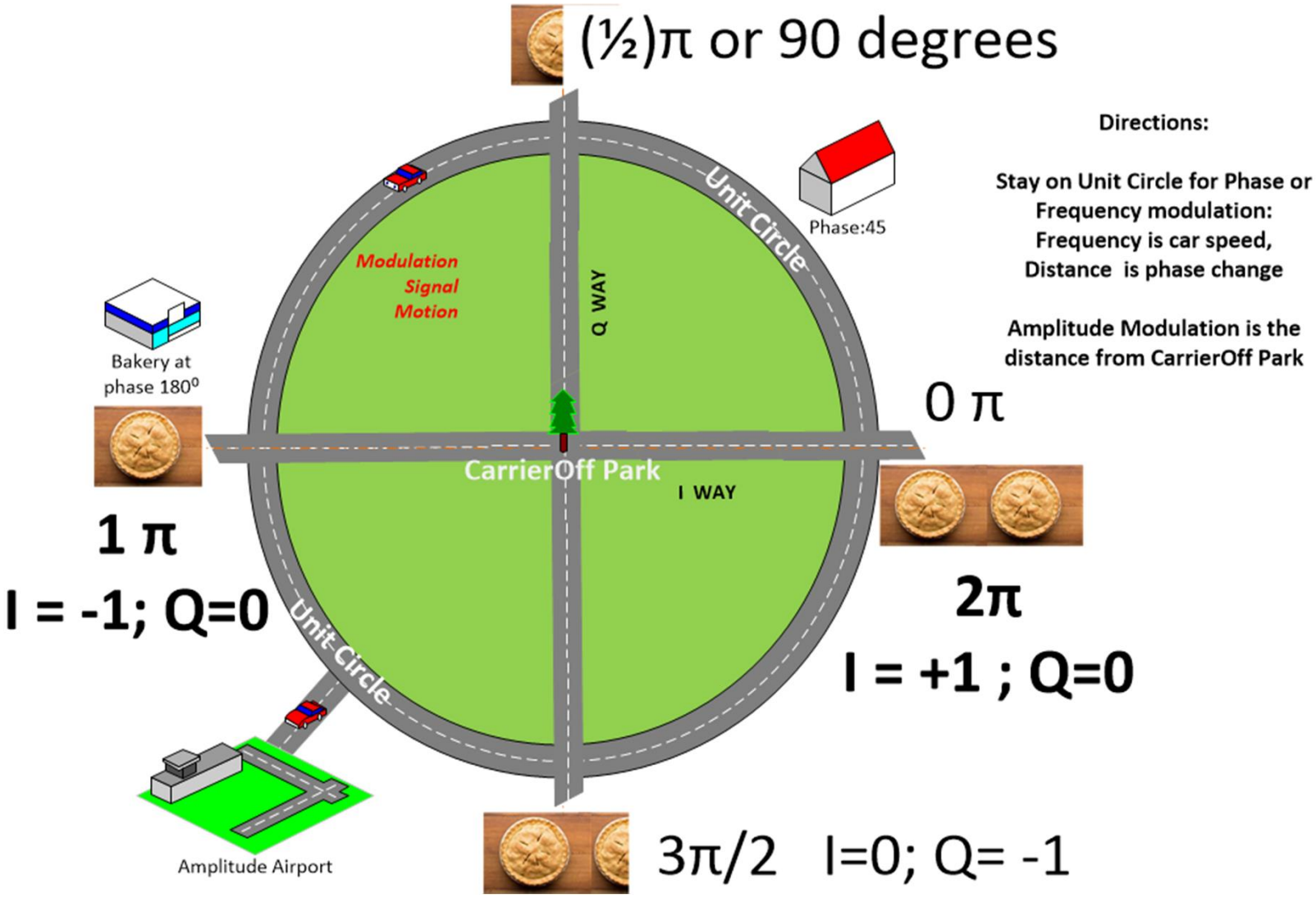


Example: Two independent CW ops on one carrier

Let’s change the message

- Using the Going Around spreadsheet
  - Change the letter:
  - P (dit dah dah dit) to
  - E and N (dit dah dit)
- Observe
  - the transmitted wave and the demodulated result.
  - the second CW operator is not affected.
- The bandwidth is the same as one CW op or two ops at half the code speed.

MOD-QUADS COUNTY MAP



Thank you for listening

Questions ?

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