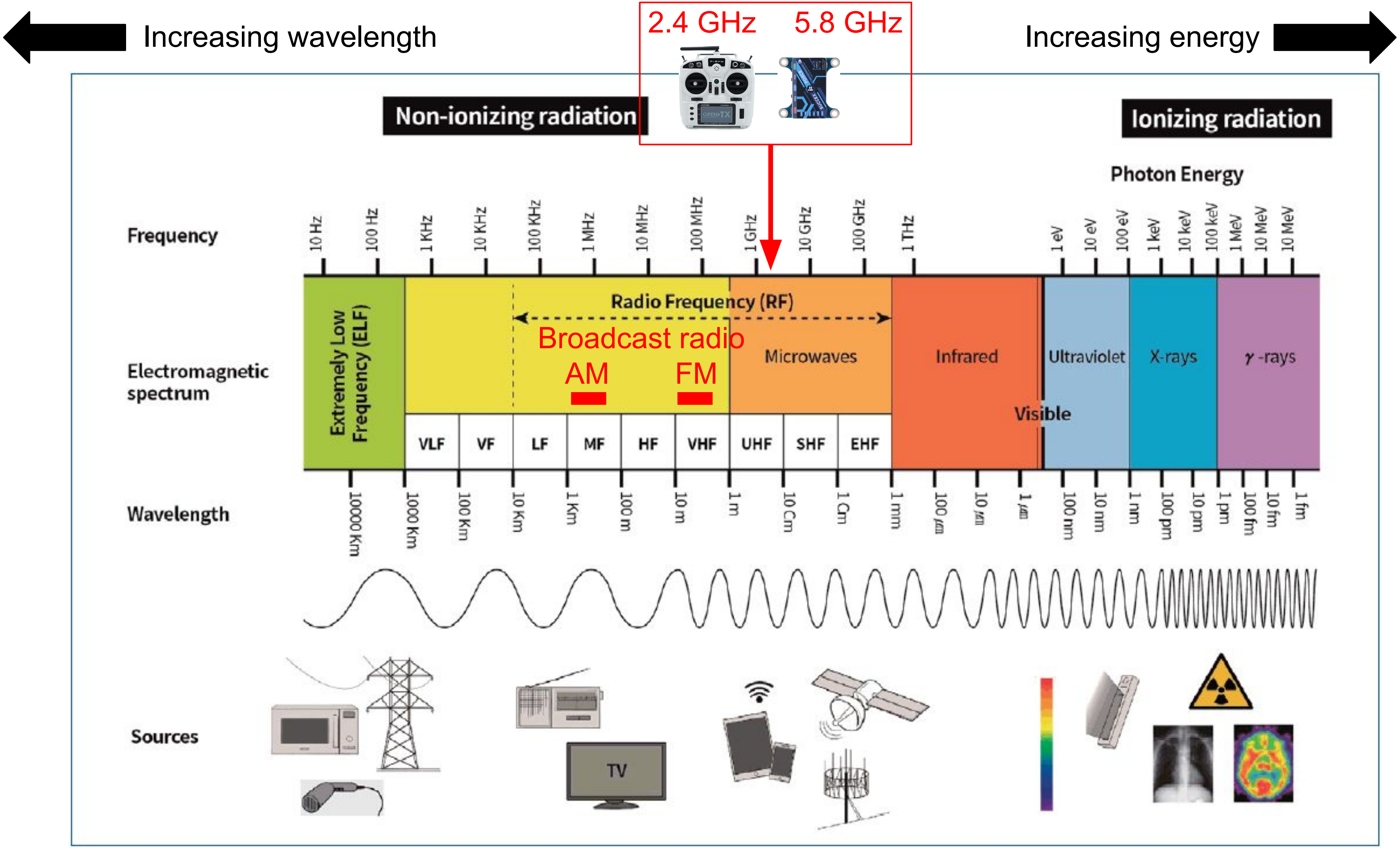
RADIO FREQUENCIES

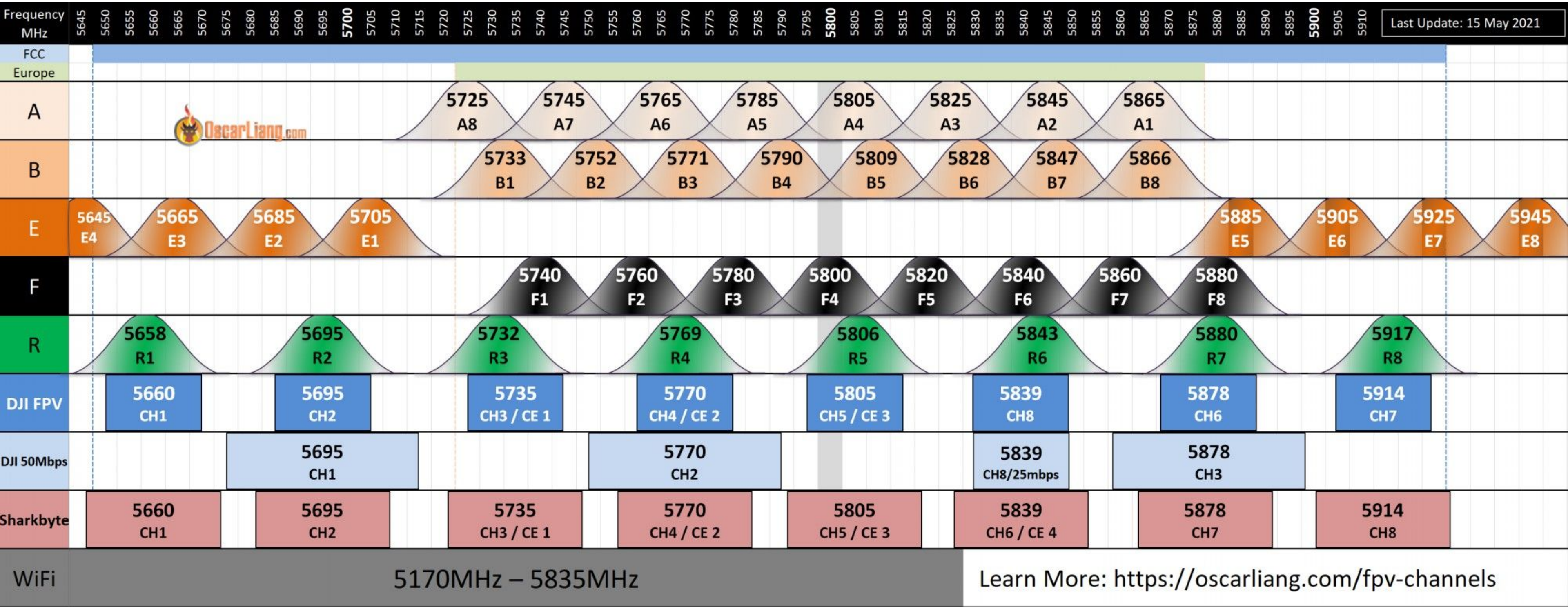
2.4 GHz

5.8 GHz



Increasing wavelength
Increasing energy
2.4 GHz
5.8 GHz
Non-ionizing radiation
Ionizing radiation
Photon Energy
Frequency
10 Hz
100 Hz
1 KHz
10 KHz
100 KHz
1 MHz
10 MHz
100 MHz
1 GHz
10 GHz
100 GHz
1 THz
1 eV
10 eV
100 eV
1 keV
10 keV
100 keV
1 MeV
10 MeV
10 MeV
Electromagnetic spectrum
Extremely Low Frequency (ELF)
Radio Frequency (RF)
Broadcast radio
AM
FM
Microwaves
Infrared
Visible
Ultraviolet
X-rays
γ -rays
VLF
VF
LF
MF
HF
VHF
UHF
SHF
EHF
Wavelength
10000 Km
1000 Km
100 Km
10 Km
1 Km
100 m
10 m
1 m
10 Cm
1 Cm
1 mm
100 μm
10 μm
1 μm
100 nm
10 nm
1 nm
100 pm
10 pm
1 pm
100 fm
10 fm
1 fm
Sources
TV

- The commonly used ~5.8GHz analog bands are A, B, E, F and R.
- The other bands are rarely used but they do exist.



Band	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8
A	5865	5845	5825	5805	5785	5765	5745	5725
B	5733	5752	5771	5790	5809	5828	5847	5866
E	5705	5685	5665	5645	5885	5905	5925	5945
F	5740	5760	5780	5800	5820	5840	5860	5880
R	5658	5695	5732	5769	5806	5843	5880	5917
D	5362	5399	5436	5473	5510	5547	5584	5621
U	5325	5348	5366	5384	5402	5420	5438	5456
O	5474	5492	5510	5528	5546	5564	5582	5600
L	5333	5373	5413	5453	5493	5533	5573	5613
H	5653	5693	5733	5773	5813	5853	5893	5933

Band A: Team BlackSheep (TBS), RangeVideo, SpyHawk, FlyCamOne USA

Band B: FlyCamOne Europe

Band R: Raceband

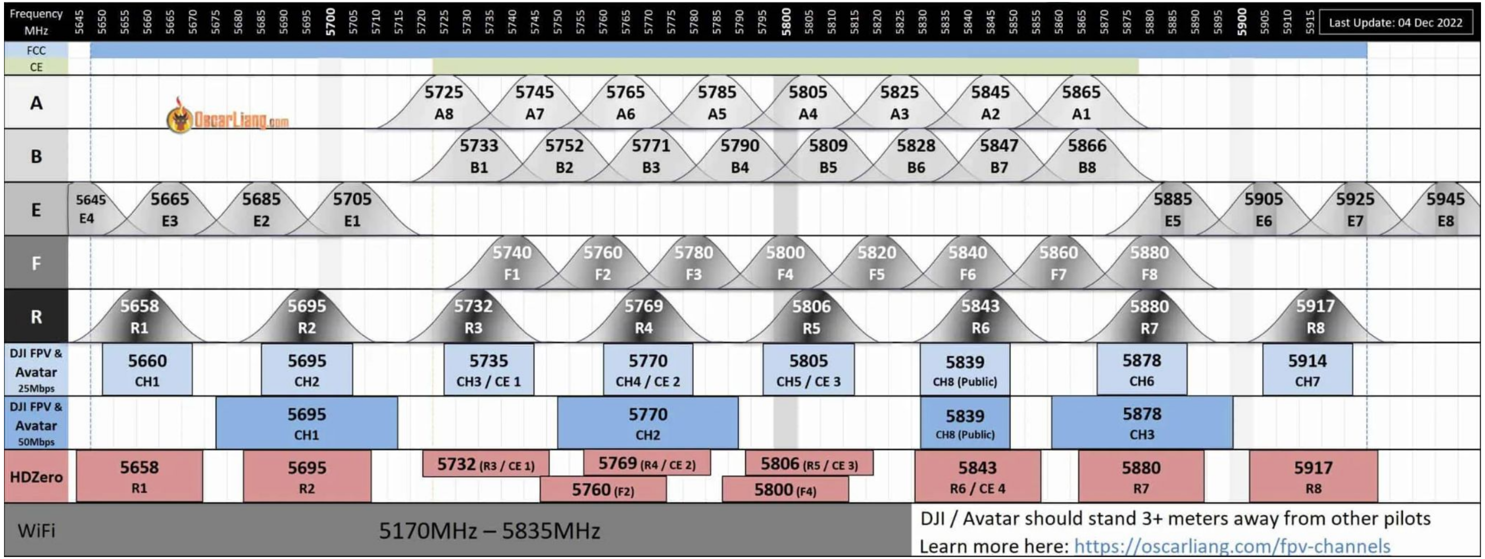
Band E: HobbyKing, Foxtech

Band F: ImmersionRC, Iftron

Band D: Diatone

Choosing a VTX channel

- When flying in a group, ask what frequency everyone is using
- Pick a free channel as far away as possible from occupied channels
- Make sure everyone sets the output power to 200 mW or lower (>200 mW requires FCC approval)
    - Indoors should be 25 mW or lower



IMD Frequency

- **I**nter**m**odulation **D**istortion - two different frequencies can form a harmonic frequency
  - Pilot 1: F2 (5760 MHz)
  - Pilot 2: F4 (5800 MHz)
  - Pilot 3: F6 (**5840 MHz**)
- Pilot 3 might get interference because of IMD
- F2 and F4 together can form a harmonic signal that appears on F6

Example:

(1) IMD frequency = F1 x 2 - F2

(2) IMD frequence = F2 x 2 - F1

5760 x 2 - 5800 = **5720 MHz**

5800 x 2 - 5760 = **5840 MHz**

Best FPV Channel for Flying in a Group

1. 5645 (E4)
2. 5685 (E2)
3. 5760 (F2)
4. 5805 (A4)
5. 5905 (E6)
6. 5945 (E8)

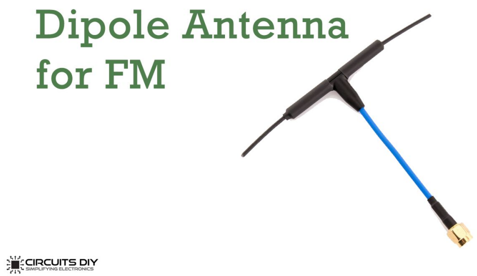
1. R1
2. R3
3. R6
4. R8

1. R1
2. R2
3. F2
4. F4
5. E5

1. R1
2. R2
3. F2
4. F4
5. R7 / R8
6. R8

Antennas

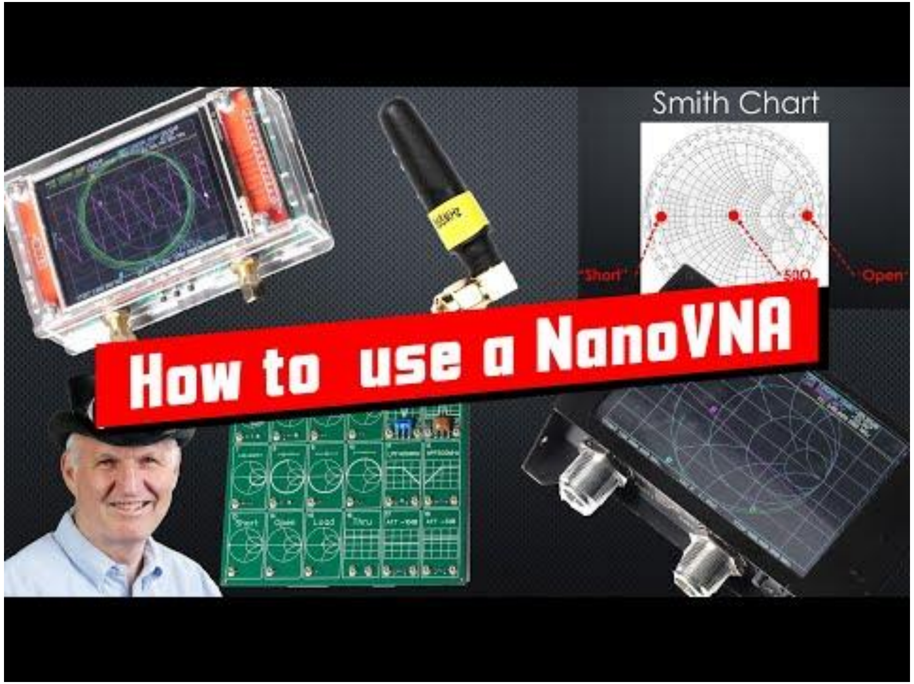
- Radio frequencies used
  - 2.4 GHz - RC Transmitter / Receiver
  - 5.8 GHz - VTX Transmitter / Receiver
  - 915 MHz - Telemetry modules
- Different antennas for different frequency ranges



Vector Network Analyzer (VNA)

- Is this antenna good or bad?
- What frequency is it best suited?

NanoVNA 50kHz-6.3GHz Vector Network Analyzer



https://youtu.be/_pjcEKQY_Tk

https://youtu.be/QJYeFpiqY8c

Spectrum Analyzer

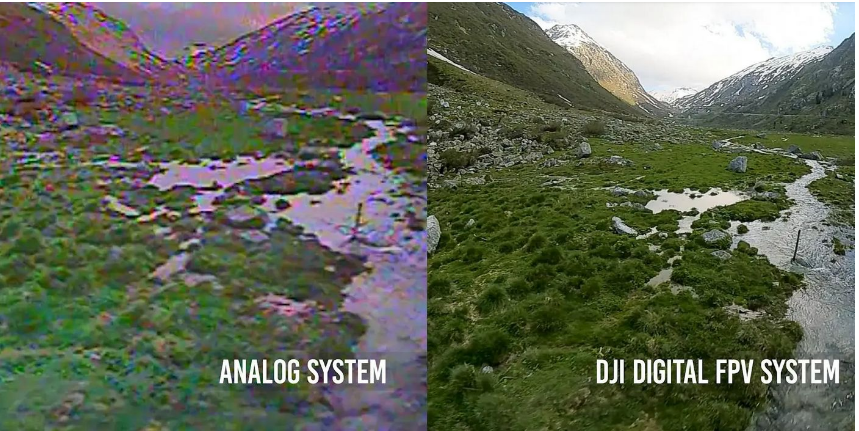
- Displays a spectrum of signal amplitudes on different frequencies
- Analyze whether signals fall within required limits, detect spurious signals, noise…

https://youtu.be/hyfZZ1VHsME

Software:
https://www.dl4jal.de/nwt4x/nwt4000.html

[NWT6000 25M-6G Frequency Sweeper Generator Simple Spectrum Network Analyzer]()

Digital Video Systems



Three Digital Video Systems - 5.8 GHz band

1. DJI
2. Walksnail Avatar
3. HD Zero

Other Applications using RF signals

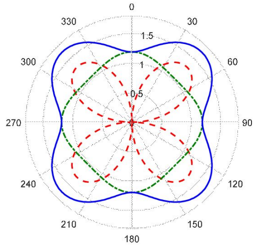
Direction Finding (DF)

- Manual Angle of Arrival (AoA)
    - Amplitude comparison
    - Antenna is physically rotated to find the maximum signal
    - Man-portable, but limitations exist

- Doppler Shift
    - Uses changes in frequency (doppler effect) to determine a bearing to the signal
    - E.g. Lojack network

Direction Finding (DF)

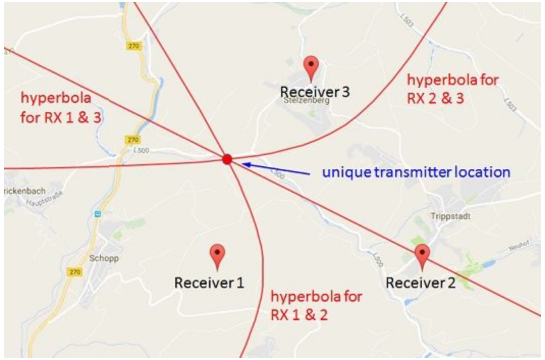
- **Watson-Watt**
  - Amplitude comparison between two orthogonal axes of antenna pairs
  - USCG Rescue 21 system (search and rescue)
    - Ideal for HF / VHF common in maritime situations



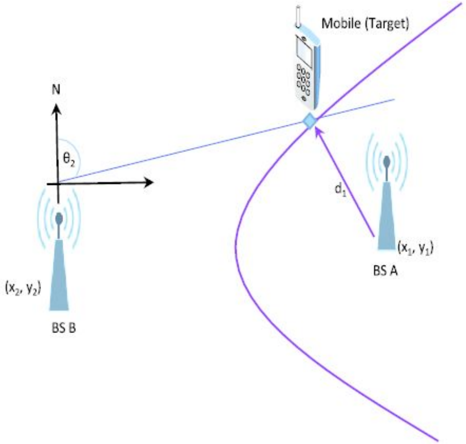
- **Correlative Interferometry**
  - Measuring phase offset
  - Bearing and bearing quality
  - High accuracy

Direction Finding (DF)

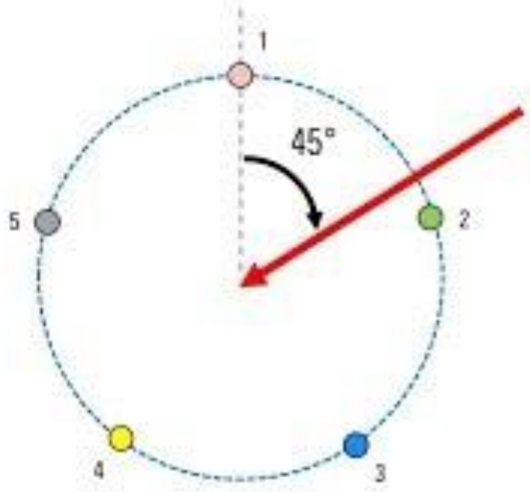
- Time Difference of Arrival (TDOA)
  - 3 or more receivers at different locations
  - Signals arrive at receivers at different times
  - E.g. Location of mobile phones (but not "find my iPhone")



- Hybrid methodology
  - Angle of arrival (AoA) + Time difference of arrival (TDOA)



How correlative interferometry works



Phase offsets

45	46	47
12	23	36
56	81	01
87	76	69
22	11	01
05	12	28