Intro to Small Unmanned Aircraft Systems & Recreational Drones

Lithium Batteries

Three types of Lithium batteries are in use today:

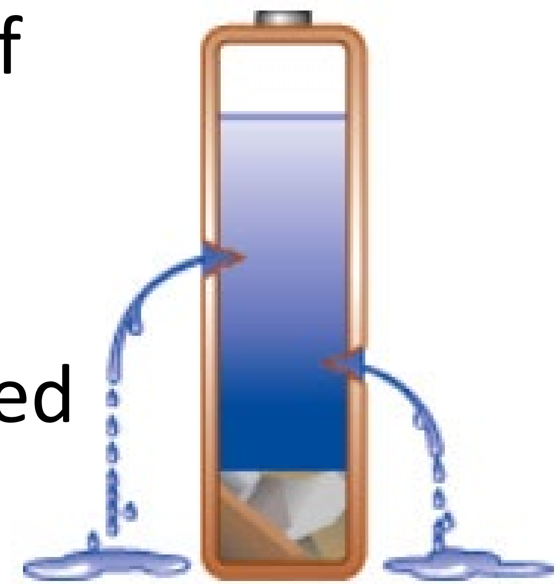
Li-Ion – Lithium Ion – for low power draw

LiPo – Lithium Polymer – for high power draw

LiFePO4 –LiFe or A123 – Lithium iron phosphate – for low power draw

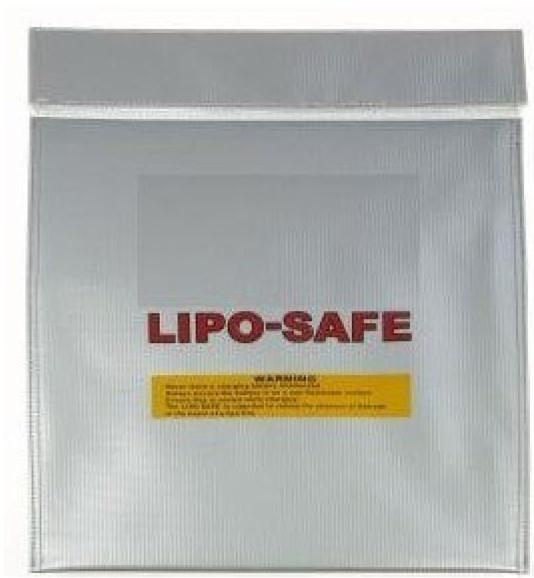
Battery Self-Discharge

Batteries self-discharge from internal chemical reactions by up to 10% of total capacity (mAh) a month.



DJI Intelligent Batteries are designed to automatically discharge to 30% capacity after two weeks of non-usage. This is called “storage mode”.

LiPo & Li-Ion Battery Safety

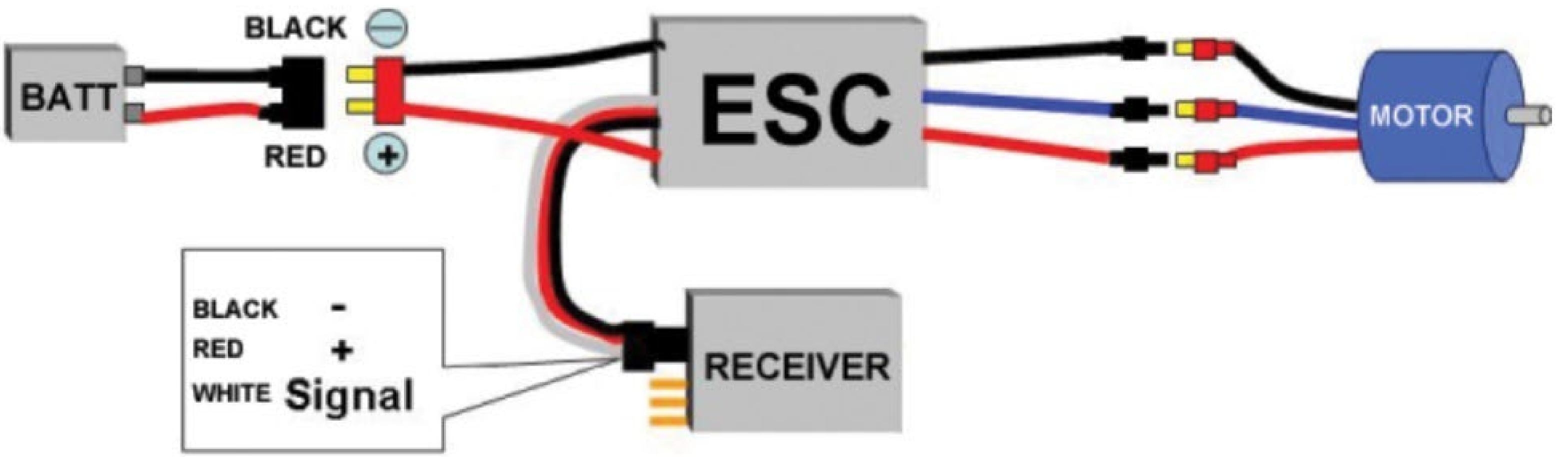


Charge LiPo batteries in a “LiPo Bag” and store in a fireproof container

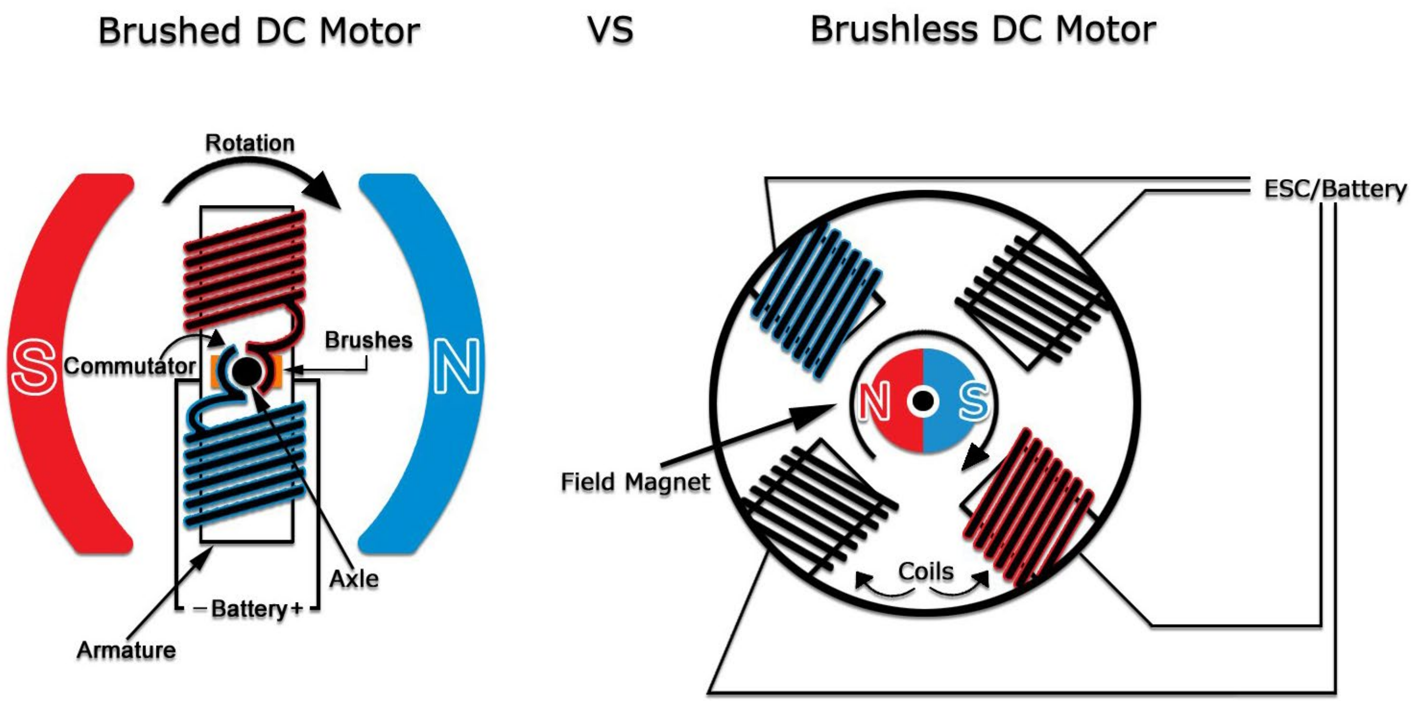
Lithium Battery Charging

- Always use the charger supplied with the battery
- All batteries lose capacity when cold (Keep them warm!)
- Lithium batteries should never be charged when the internal battery temperature is below 32º F (0º C)

Electronic Speed Control (ESC)



Brush vs Brushless DC Motors



Brushless DC motors used in drones are 85-90% efficient whereas **brushed DC motors** are 35-40% efficient. This difference in efficiency means that brushless motors turn more power into rotational force and less is lost as friction and heat.

Brushless DC Motor
(BLDC)

Six-Axis Stabilization

3 gyros automatically steady the aircraft:

- Fore & aft tilt (**pitch**)
- Right & left tilt (**roll**),
- Right & left rotation (**yaw**)

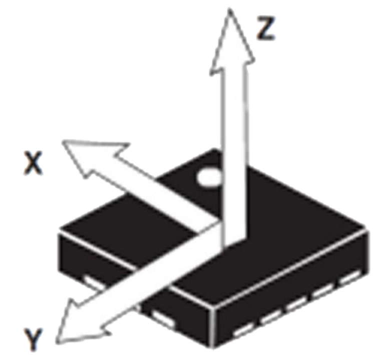
3 accelerometers sense movement along the

–x, – y & –z axes.

Accelerometers allow quadcopters to sense and compensate for sudden wind gusts.

Gyroscopes

A rotating mechanical gyroscope like those found on ships uses gyroscopic forces to detect changes in rotation.



A Piezo gyroscope uses the phenomenon of Coriolis force to detect changes in angular velocity (rotation) and acceleration in three directions.

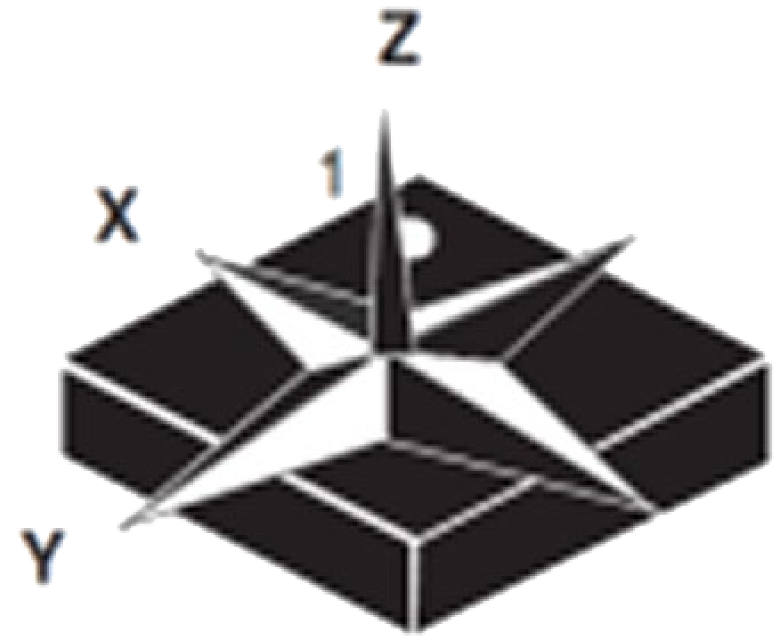
A gyroscope indicates angular rate of change.

Inertial Measurement Unit (IMU)

The IMU contains the gyroscopes and accelerometers that stabilize the drone.

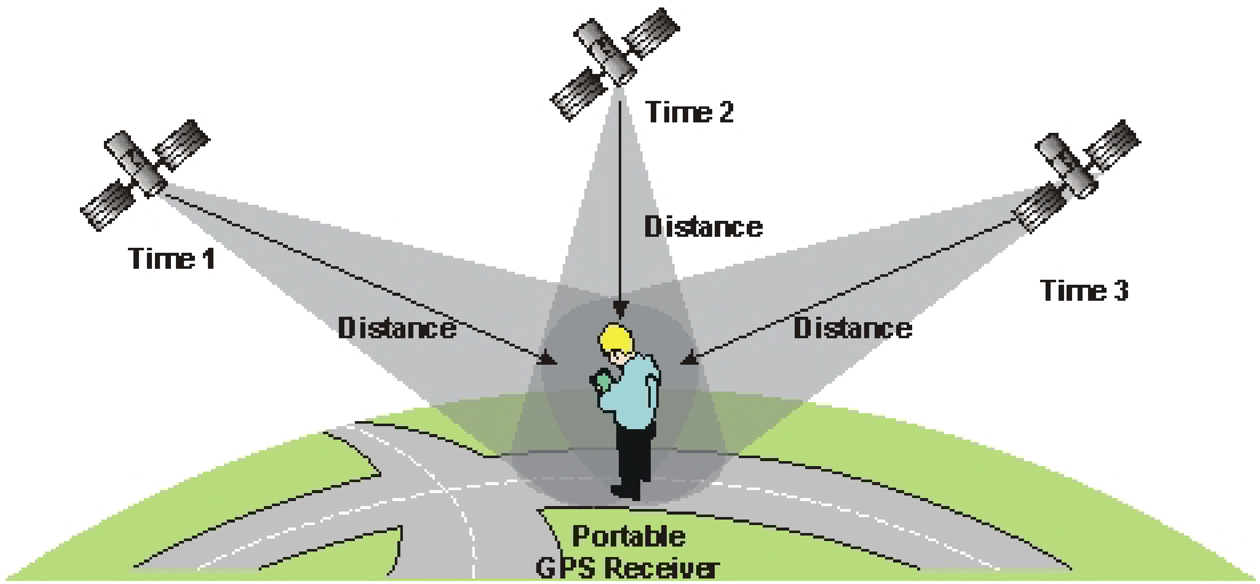
Magnetometers

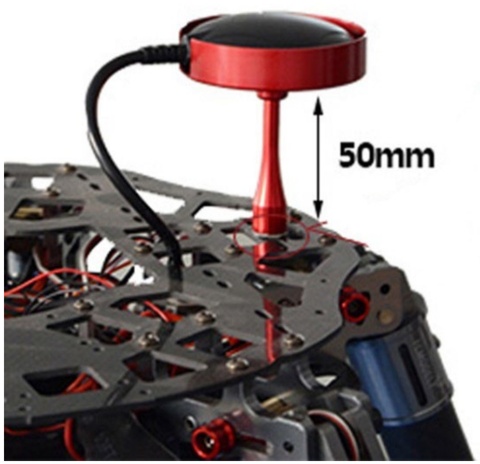
Magnetometers measure orientation relative to the Earth's poles.



A magnetometer indicates orientation.

Global Positioning System (GPS)





GPS is owned by the US Government and operated by the United States Space Force.

Other Global Positioning Systems

- **GLONASS** – Russia's global navigation system. Fully operational worldwide in 2011.
- **Galileo** – a global system developed by the European Union and other partner countries was fully operational in 2019.
- **BeiDou** – People's Republic of China's regional system, originally limited to Asia and the West Pacific, now worldwide with millimeter-level accuracy,
- **IRNSS** - A regional navigation system developed by the Indian Space Research Organization.
- **QZSS** - A regional navigation system developed by the Japanese Government.

Each system has its own satellites orbiting from 11,000 to 18,000 miles above the Earth. The International Space Station is 254 miles. Geosynchronous orbit is 26,000 miles.

Other Sensors

- **Barometers** – measure change in atmospheric pressure related to altitude change.
- **Lidar (**Light Detection and Ranging) – uses a laser beam to measure distance. Can be used to maintain constant altitude, collision avoidance or record ground images.
- **Tilt Sensors** – augment IMU by sensing alignment with the horizon.
- **Infrared Sensors** – for tracking lap times when racing

R/C Transmitters (TX) & Receivers (RX)

Factors That Affect Range –

- Frequency – higher frequencies have a shorter range and less penetration of obstacles
- Broadcast Power
- Antenna Configuration – single vs multiple (dual diversity)
- Antenna Height – higher above the ground is better

R/C Radio Frequencies

R/C radio equipment can operate on five different frequency ranges: 5.8 GHz, 2.4 GHZ, 1.2 GHz , 900 MHz, 75MHz and 72 MHz

- ✓ 72 MHz (Aircraft) and 75 MHz (Surface) are for analog signals. They are mainly used on older R/C equipment.
- ✓ 1.2 GHz and 900 MHz are infrequently used, because there are only two legal channels, 1280 MHz and 910 MHz

Devices that broadcast on 2.4 or 5.8 GHz

- Cordless Phones
- Baby Monitors
- Bluetooth Devices
- Wireless USB
- USB 3.0
- Older Microwave Ovens
- WiFi Networks & Routers (including Cell Phone WiFi)
- Video Devices (Smart TVs, Cameras)
- Zigbee (Smart Home Devices)
- Amateur Radio & Video
- Other Drones and R/C Aircraft

2.4 GHz & 5.8 GHz Frequencies

- **2.4 GHz** – 130 mm (5.1”) wavelength
  - Used in almost all R/C transmitters
  - Maximum range of 4.3 miles (7.0 km) with no obstructions and free of interference
  - Slightly heavier weight and longer antenna
- **5.8 GHz** – 5 mm (1.9”) wavelength
  - Used for First Person View (FPV) video systems
  - Maximum range up to 1.7 mile (2.7 km) with no obstructions, free of interference and 600 mW
  - Slightly lighter weight and shorter antenna
- Maximum Range is reduced by half when either antenna is close to the ground!

Binding Transmitter to Receiver

- For the system to work, the Transmitter and Receiver must “bind” together and form a unique synchronized pair.

- While different brand transmitters broadcast on the same frequencies, they use incompatible operating systems.

Caution!

Frequency hopping is primarily needed for our aircraft to survive 2.4 GHz commercial WiFi products that can interfere with our radios. One of the most threatening examples is a high powered 2.4 GHz Point-to-Point video link using a high gain (i.e., narrow beam) antenna. High gain antennas for outdoor WiFi are also a concern. Don’t fly near the beams on College Hill or downtown Cedar Falls!

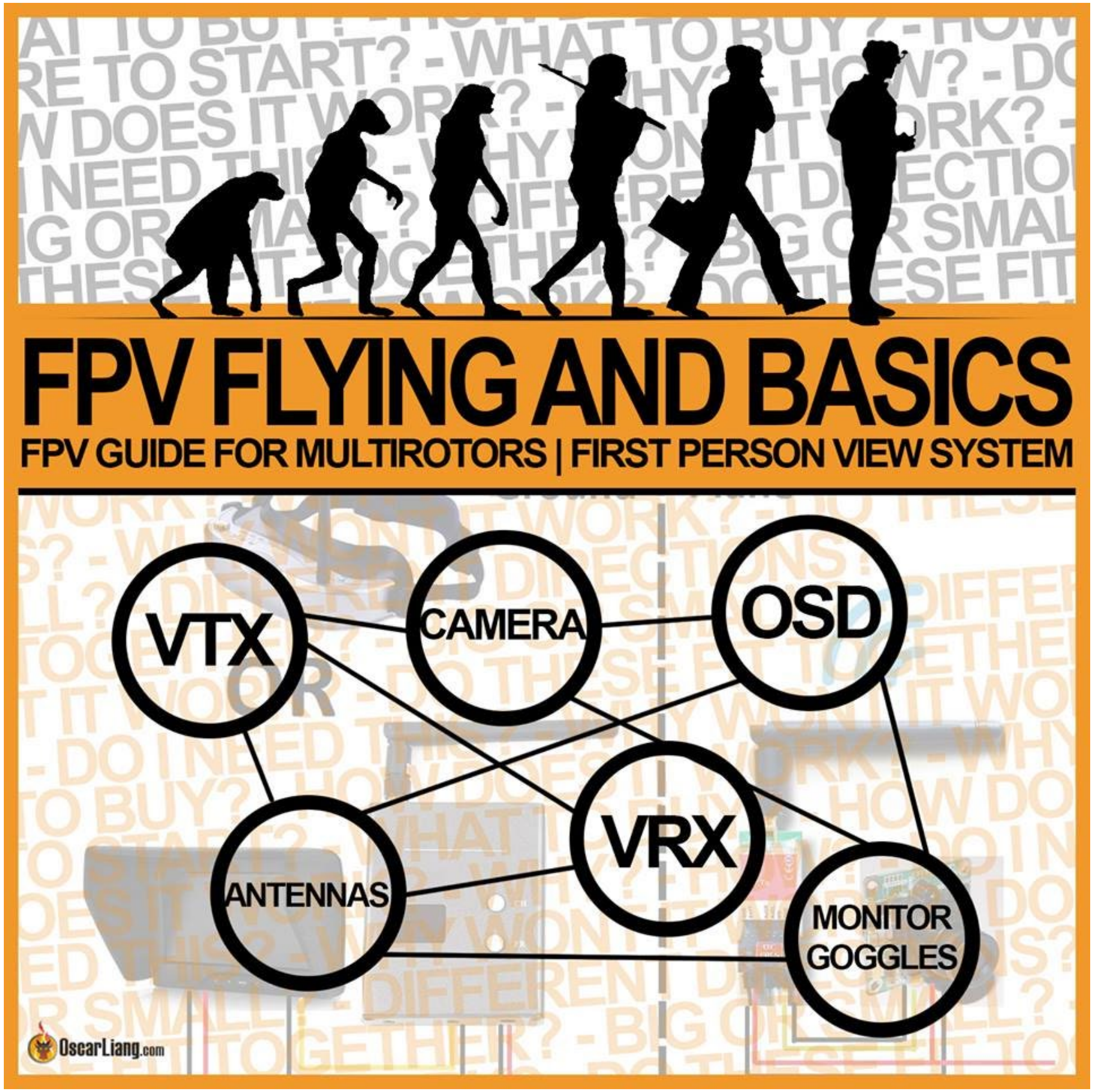
Another Caution!

Carbon Fiber blocks receiver signals.

Locate your receiver antenna away from carbon fiber frames and rotor arms.

Use special receivers inside a carbon fiber fuselage.

First Person View (FPV)



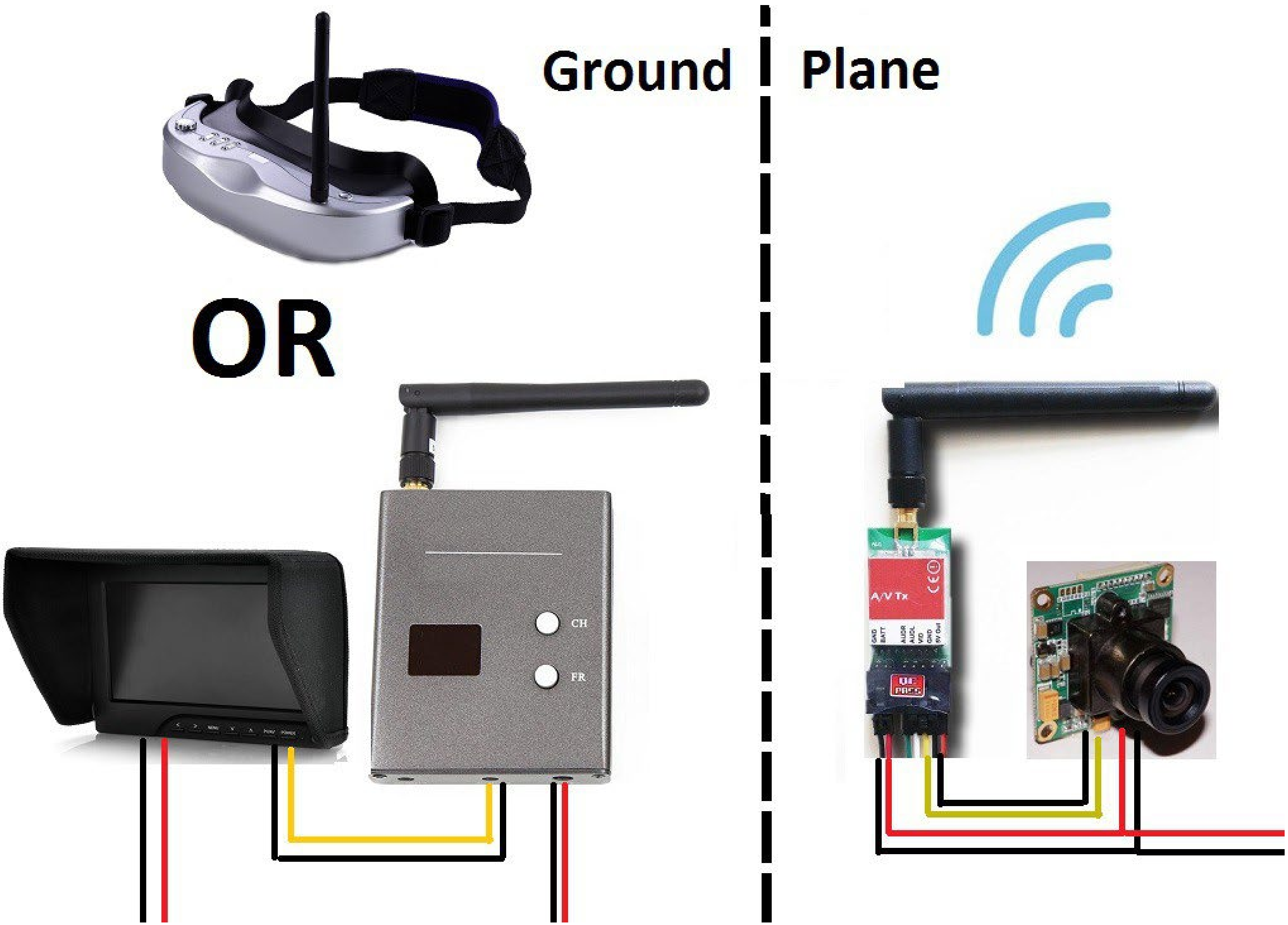
FPV systems typicaly use 5.8 GHz

- The 5.8 GHz frequency band is made up of 300 channels, each channel is 1 MHz wide
- Video signals need a continuous stream of data with a 35 MHz to 40 MHz of band separation
- Video signals operating in the same RF environment as R/C transmitters will have interference (static, snow or ghosting) or even loss of signal
- Using 5.8 GHz for FPV will give a much cleaner video image than 2.4 GHz, but have a shorter range

First Person View (FPV)

- **FPV Camera – analog or digital**
- **Video Transmitter** (VTX)
- **Video Receiver** (VRX)
- **FPV Goggles** or **Monitor**
- **Antennas**
- **On-Screen Display** (OSD)
- **Video Recorder** (DVR)

First Person View (FPV)



Low Latency

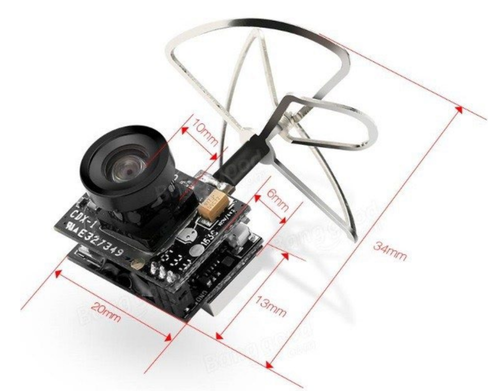
- “Delay”, “latency” and “lag” are all terms used to describe the amount of time it takes from your FPV camera capturing an image to that image being displayed on your screen.
- Analog FPV cameras have 20ms-40ms delay. HD digital video cameras such as GoPro have 100ms-140ms delay.
- FPV racing cameras transmit a low-quality standard definition (SD) analog signal for low latency.
- The faster you fly the bigger the impact of latency. A 100ms delay when flying at 50 mph can mean your drone will travel about 1.7m (5 ½ feet) before you see the video.

Wide Dynamic Range

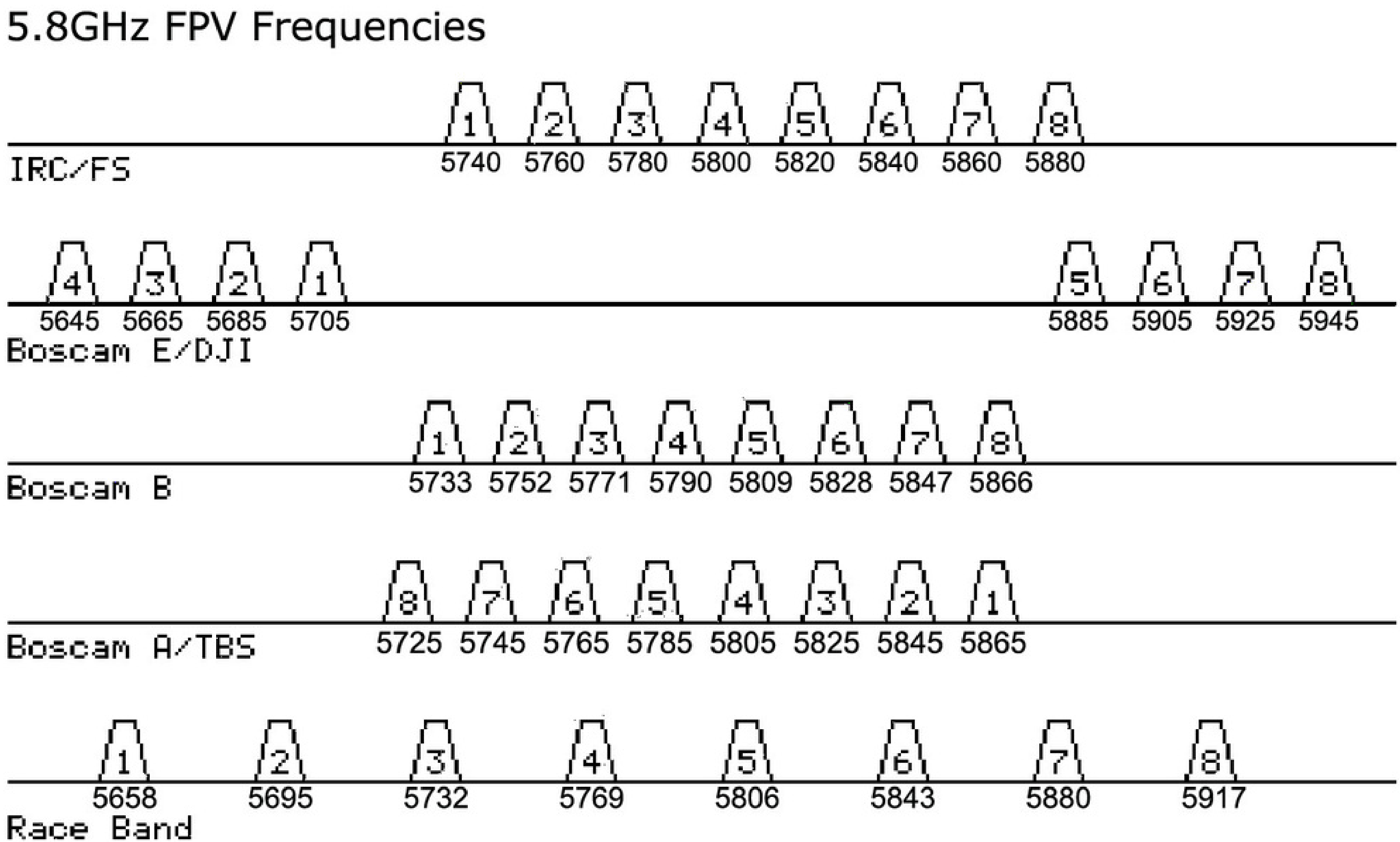
- The dynamic range of your FPV camera dictates how well your camera can record the details in very dark and very bright areas of an image.

Video Broadcast Channels

- The 5.8 GHz frequency range is divided into bands with 8 channels in each band.
- Different manufacturers choose different channels and channel spacing.
- Recently manufacturers have standardized on the “Race Band” or “Band C”



Video Broadcast Channels



Race Band

- Released in 2015
- 8 channels spaced 37 MHz apart

Channels	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
Race Band	5658	5695	5732	5769	5806	5843	5880	5917

Video System Range

- Wi-Fi – 1.2 miles @ 2.4 GHz
- Wi-Fi – 2.5 miles @ 5.8 GHz
- Lightbridge – 4.3 miles @ 2.4 GHz
- Lightbridge 2.0 – 3.1 miles @ 2.4/5.8 GHz
- OcuSync – 4.3 miles @ 2.4 GHz
- OcuSync 2.0 – 6.2 miles @ 2.4/5.8 GHz
- OcuSync 3.0 – 7.5 miles @ 2.4/5.8 GHz
- Autel EVO – 4.3 miles @ 2.4 GHz

DJI Video Systems

- **DJI WiFi**
  - Range of up to 1.2 to 2.5 miles
  - Latency of 150 ms or more
  - Dual or 5.8 GHz
  - Live Video is 720P
- **DJI Lightbridge**
  - Range of up to 4.3 miles
  - Latency as low as 75 ms (may be as high as 220 ms)
  - 2.4 GHz only (single frequency)
  - 720p or 1080p

DJI Video Systems

- **DJI OcuSync (original)**
  – Range of up to 4.3 miles
  – Latency as low as 50 ms (may be as high as 170 ms in some modes)
  – 5.8 GHz or 2.4 GHz
  – 720P & 1080p (720P has lower latency & longer range)

DJI Video Systems

- **DJI OcuSync 2.0**
  - **Combines OcuSync and Lightbridge**
  - Range of up to 6.2 miles
  - Latency as low as 50 ms (may be as high as 130 ms in some modes)
  - Auto dual band 5.8 GHz or 2.4 GHz
  - 720P & 1080p (1080p has improved latency & range over OcuSync 1)
  - Firmware can be updated
  - Lower cost hardware

DJI Video Systems

- **DJI OcuSync 3.0**
  - Range of up to 7.5 miles
  - 4 antennas
  - Improved Latency – Low Latency mode (28ms) – High Quality mode (40 ms)
  - Auto dual band 5.8 GHz or 2.4 GHz
  - 4K video at 60 fps (120 fps at lower resolutions)
  - Older versions cannot be upgraded to OcuSync 3.0

Antenna

- **Dipole Antenna** (Rubber Ducky)
  - Directional
  - Signal reception from the side of the antenna
  - sensitive to multi-pathing when the video signal bounces off of hard objects such as a wall or tree

- **Circular Polarized**
  - Omni-directional
  - Signal reception from all directions
  - RH or LH, 3-lobed (cloverleaf) or 4-lobed (skew-planar)
    - Always match the transmitter and receiver antenna types

Antennas are frequency range specific (2.4 GHz or 5.8 GHz)

Never power up a receiver without an antenna connected!

Video Transmitter (VTX) Power

- 25 mW – good for micro drones & indoor racing with many racers – no license required
- 200 mW – good for outdoor racing – FCC amateur license required
- 600 mW – good for solo flying – maximum power and range – FCC amateur license required – more prone to multi-pathing

mW = milliWatt or 1/1000 of a watt

FCC = Federal Communications Commission Amateur Radio Operators License (HAM)

Video Receiver (VRX) **FPV Goggles** or **Monitor**

- The Video Transmitter sends the signal to the Video Receiver which converts it to an electronic image that can be stored on a DVR or displayed in goggles or on a monitor (smart phone, LCD display, tablet or iPad).
- Goggles frequently incorporate the Video Receiver into the goggles.
- Form Factor should match (4:3 or 16:9)

Monitor

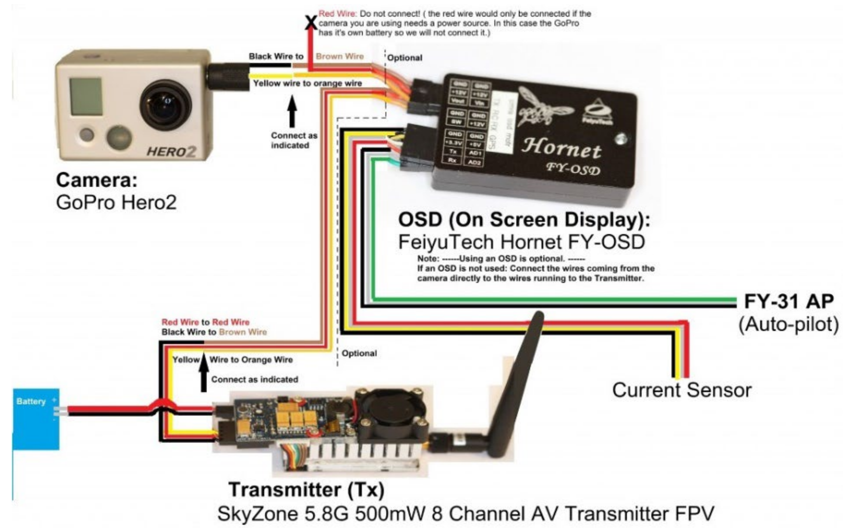
- Monitors are the least expensive option for a display. You may already have an iPad, tablet or smartphone. Small LCD displays are available for $50 to $250 and use standard Wi-Fi frequencies.
- Screens may not be very visible in bright sunlight.
- Transmitter & Receiver must be compatible

Goggles

- Goggles are a more expensive option but give a good view outdoors in sunshine. Cost is from $300 to $500. Receiver is built-in.
- May not be compatible with all video transmitters.

Antenna & Battery not shown

On Screen Display (OSD)



OSD can be built-in to the Flight Controller


Any
Questions