2.4 GHz Radio Control

Anyone can do a simple internet search and get accurate information on how the radio control systems of years gone by operate or operated as well as their failings and shortcomings. However if you were to do the same search for information relevant to modern digital ISM band 2.4 GHz digital radio control systems you may find actual/factual information very difficult to locate and even find a large amount of dangerously inaccurate information and flawed opinions.

Microprocessors are now the norm in modern radio control systems and yet the way the transmitter and receiver communicate seems to be almost secretive. I have contacted manufacturers directly only to find that the engineering teams are impossible to contact directly and the company representatives have shown a lack of any real technical knowledge, (or understanding), often actually providing information that can be easily proved to be false, (and sometimes very wrong and actually dangerous).

This little article is just to help fix a few obvious misunderstandings as to how the modern digital radio control systems actually communicate and will not be going deeply into the various protocols or the individual operating firmware used, (as loaded in the OEM equipments). If this article improves your understanding and possibly prompts you to do a little research and investigation, for your own safety, then it has been of some value.

Background:

There is a lot of fear, misinformation, assumptions, and false assertions on how the current generation of 2.4GHz digital radio control equipment actually works and what the safest way to setup your radio is. Due to my support for a number of students and other club members I have obtained experience across a wide range of equipments and non-OEM firmware packages.

I have seen persons actually complain that their radio system has stability and other performance issues over and over whilst their guesses and the expert opinions, provided by the club elites, as to the cause of the problems, have been so far from the actual cause that the resulting remedial actions have introduced even more issues and safety hazards. Microprocessor based systems are so inherently stable and predictable that actually the instability and other issues are related to improper understanding, setup, usage and handling. When I first started back into flying RC model aircraft, after almost 40 years, I also initially followed the advice of the experienced club persons only to learn, (at my own cost), that what I was being told was effectively wrong, illegal or actually quite dangerous.

The reason behind the work and research that I have done so far was my developing of a radio control interface for single handed operation. Modern radio control devices actually require 2 hands for safe operation which actually excludes many military service veterans from the therapeutic benefits and business opportunities of operating model aircraft and drones. A person with a single functional hand could also become fully incapacitated by a serious prop strike and so ACTUAL and DEMONSTRABLE safety was a fundamental and primary requirement. Zero incidents and personal injury can be so easily achieved. The supplied equipment manuals do not actually reflect the tested operation of the radio equipments and so research was required. Another primary requirement for the single handed radio controller interface was that it was able to be used on any of the current digital radio equipment offerings and so true performance and applied technology based research was required across an apparent plethora of different radio systems.

The first step I took was to seek information on the regulatory requirements for equipment type approval and suddenly everything appeared so very familiar to me. My technical qualifications are in electronics and communications with 30 years in wireless computer communications, (early WLAN through to modern WiFi).

Regulatory requirements:

FCC Part 15C, Class licensing, LIPD, ISM band operation, and even the choice of the 2.4GHz band, the similarities just kept adding up. Actually the modern digital radio control systems appear, technically, to be very similar to the earliest generations of wireless computer networking devices but far less capable and some limited support for single direction transmissions at extreme range. It took IEEE intervention and standards writing for the early WLAN technology to evolve into the current WiFi equipments. Sadly I could not find any evidence of the IEEE having any interest in standardising Digital radio control equipments, currently.

The first thing to consider is that the same radio frequency band is used for a lot of other “Unlicensed” services and other devices. Two of the most notable are Microwave ovens and of course WiFi equipments. At this time the IEEE has not written a standard for this class of wireless communication equipment and so there are a plethora of different transmitted radio protocols currently available and a lack of accurate operating manuals describing the features and operational requirements attributable to the digital radio technology.

In order to be able to be legally used on the 2.4GHz band all radio control transmitters that are type approved must comply with the U.S. regulatory requirements of FCC Part 15C. This regulation stipulates that each transmitting device must not create interference to any other devices using the band and that the device must accept all interference it receives even if the interference may cause improper or undesired device operation.

To comply with FCC Part 15C, (which is also a requirement of WiFi devices that also use the 2.4GHz band), each transmitter uses what is called Carrier Sense Multiple Access (CSMA), or is simplified to Collision Avoidance, (CA). Effectively prior to each transmission from a transmitting device, (controller or receiver), the device must check to verify that the radio frequency/channel to be utilised is actually free and clear to use. If the frequency is in use by another device then the device that is to transmit must not transmit and should wait until the channel is clear or the device is moved to another channel that is not currently in use for its transmission, as per its frequency hopping requirements. This CA requirement is equally applicable to radio control transmitters and receivers as each device has both a transmitter and a receiver as part of their design and construction.

Analogue Radio:

The previous generations of radio equipments used an all analogue system with the possible exclusion of an Analogue to digital pulse width generating device. This single device allowed for the analogue stick inputs to be used to determine a PPM, (Pulse Position Modulation), or PWM, (Pulse Width Modulation), output to the transmitter modulator circuitry. As the width of the generated pulse/s was proportional to the control stick position the entire system was given the name of Digital Proportional radio control system. The information that was outputted on the servo connections of the receiver had a pulse width range of approximately 1 milliseconds, (at minimum), to approximately 2 Milliseconds, (at maximum). These standard output pulse widths set the standard for the servos in use then and still in use now.

Unfortunately the radio technology used by the analogue radio systems was narrowband with a transmitted bandwidth measured in KHz and a modulated signal that was a series of sequential time blocks. The transmitter transmitted the entire time it was powered on and did not have a requirement to avoid causing interference with another transmission already on the operating radio channel.

If a block of information was damaged, or missing, all subsequent channels would be supplied incorrect information. Throttle as the first channel seems like it was a good idea at the time! Being narrow band and on a single fixed frequency, interference was a notable problem and so was noise, (both internally generated and atmospheric). Added to those issues was the simple fact that the lowest of the allocated frequencies in use at the time, (less than 40MHz), could suffer from interfering signals from around the globe due to atmospheric features such as atmospheric skip and ducting. Looking back, I do not know how I survived, but I do know why I do not have any of my planes from that time, still flying.

Digital radio basics:

To differentiate from narrow band radio technologies the term “Wireless” was used for the newer “Spread Spectrum” communication technologies. The “W” in WLAN stands for Wireless and the “Wi” in WiFI stands for Wireless also. With the modern 2.4GHz digital radio control systems the aim is effectively to represent the control stick positional information of the transmitter/controller as a PWM signal ranging from 1mS to 2mS at the channel outputs of the receiver, which is the required operating information range for the current range of servos and even ESCs, (Electronic Speed Controllers). Modulation types like DSM2/X, AFHDS, ACCST, FASST and all of the other 2.4GHz modulation types use a version of either direct sequence or frequency hopping wireless or Spread Spectrum techniques.

It is important to understand that what happens between the control stick and the receiver outputs is entirely at the whim of the design engineers and is controlled by the firmware loaded, though there are a few somewhat standard or common shortcuts cuts in used by the various engineering teams.

A modern Digital radio control system uses a bi-directional information exchange between the transmitter/controller and the paired/bound receiver. Each device, (Tx and Rx) uses a spread spectrum transceiver chip to handle the communication under the control of microprocessors. At the start of each transmission there is a synchronisation series of pulses that are of totally different duration to that of the data stream and so cannot be confused as such. At the cessation of the synchronisation stream, (also referred to as the Preamble), the receiver knows that the actual data stream portion of the communication commences and is therefore ready to receive the synchronised data. When the receiver is being bound to the transmitter/controller it receives, and stores in memory, the GUID, (Globally Unique Identifier), of the transmitter and transmits its own GUID to the transmitter where the receiver GUID is stored.

After being bound together each and every communication data stream, between the transmitter and receiver, will have both the controller and receiver GUIDs included as the source and destination addresses. In addition each communication from the controller will have a long series of digital numbers relating to the control channel information being transmitted. In simple terms the control data will be of a format of the channel number followed by the numerical control value, this information is repeated for each control channel the system supports, (in sequence but it is not a necessity just a legacy convention).

Where receiver telemetry is available, the receiver will transmit back to the controller both its acknowledgements of the received data but also the values of its installed telemetry devices using a similar data channel number followed by the associated numerical value. If it all sounds vaguely like WLAN communication you would be correct. Actually the transceiver chips used currently can trace their origins to the first series of Wireless equipments. Please note that WLAN and the digital radio control systems do not accept, acknowledge, or process any data that is the wrong format, missing correct identification, or is deemed to be corrupted and unrecoverable. Such information is always discarded outright and ignored!

With 2.4GHz digital radio control, a receiver device will not respond to any signal that is not addressed to it from its bound partner and will reject all other signals. This is why failsafe is required and also why the receivers have specific safety features in their operating firmware. I will touch on the firmware safety of operation in the safety section of this article.

All control channel outputs as well as any PPM/PWM or Sbus/Ibus outputs are reconstructed by the receiver microprocessor from the digital number values found in the received data stream. Similarly any similar outputs used by the transmitter are similarly generated by its microprocessor AND any PWM input supplied from a buddy-boxed transmitter is converted into the digital number/control channel format for transmission to the paired receiver.

Digital Radio Equipment:

With the modern 2.4GHz radio control equipment there are very significant differences in almost all aspects of their operation and operating environment when compared with earlier analogue radio control radio equipment.

With a 2.4GHz digital radio control system the operating firmware determines both the systems radio protocol and its system default behaviours or features. Most of the current range of transmitters and receivers use a non-volatile memory for binding information, (partner GUID), storage BUT some of the cheaper and smaller RC toys only use volatile memory and so their transmitters also use an AUTOBIND feature each time they are powered up.

Now comes the most difficult part for someone unfamiliar with the digital radio technologies and their requirements to fully comprehend or understand. The 2.4GHz digital radio control systems information exchanged between a receiver and a transmitter is actually a digital code with a large digital number being used for each control channel's positional information. The transmitted information is encoded using a large code for each bit of the transmission such that the code is different and unable to be confused with the opposite logic state, (a 1 or a Zero).

In order to transmit the large string of digital numbers, each bit of which is transmitted as a long digital code, requires some high speed modulation. The modulation used is now referred to as Wireless Transmission but in the older days it was referred to as Spread Spectrum radio transmission. Spread spectrum comes in 3 basic flavours each with its own benefits and disadvantages, (and of course those who support blindly a particularly flavour, normally the manufacturers and their representatives). The three flavours are Direct Sequence, Frequency Hopping, and of course any combination of the first two.

Direct sequence has normally a higher data throughput capacity and transmits across wider channels on the band whereas Frequency Hopping actually transmits a narrower signal and therefore has more channels to choose from. Here it starts to get a little funky! A direct sequence signal will more easily recognise another wideband transmission but can often fail to recognise a narrower FH transmission as being a valid transmission, but a FH device has a larger number of channels to choose from and has a higher peak power for the same amount of transmitted power. The transmitted power of a spread spectrum device is a sum of all of its transmitted power applied across the entire channel.

Now any particular radio channel may have a large number of devices using it at the same time BUT such that only one of them transmits at a time. This is the MA, (Multiple Access), of the earlier mentioned CSMA. Because of the high speed of the transmission and hence the short duration of each transmission, sharing the radio channel is not a serious issue UNTIL the number of devices requiring to transmit becomes very high in which case deferrals can lead to a cessation of transmission due to a lack of available channel space, (time). For those who are into computer networking this effect can be seen to be similar to a DOS, (Denial of Service attack). Fortunately the deferral can be overcome if the transmitter changes its operating channel to a clear channel.

The channel selection/usage sequence is first determined by the transmitter/controller when it is first turned on. The controller scans all available channels and selects a number for its future use. When the Transmitter establishes communication with its paired receiver the transmitter sends the "Channel list" to the receiver before full communication is established and the control data is forwarded. Please note that where congestion increases on the selected channels the transmitter will do additional channel scans, (between scheduled transmissions), to establish a better channel list and forward this list to the receiver during its next information exchange.

Please note that in a 2.4GHz radio control setup the actual transmitter/controller has greater transmit power than the paired receiver for what should be obvious reasons. This means that the effective range of the transmitter/controller. (Transmitter to receiver), is greater than that of its paired receiver, (in the reverse direction). As the model control requirements are effectively only in one direction whilst airborne this is not an issue and allows for greater model battery life and receiver cost reduction. For those who use radio equipment that has inbuilt in telemetry you will often observe that the telemetry signal may be lost and the model is still flying quite controllably. The difference in transmitted power between a transmitter/controller and its paired receiver device is the reason. Be aware that the actual range difference is not excessive and so a loss of telemetry is a warning of impending LOS if you fly much further away from the transmitter.

Just like WiFi the received communication data stream is subject to error correction but unlike WiFi, currently, 2.4GHz radio transmissions do NOT use any form of encryption or transmission security. It is possible for someone to purchase a hacking kit and for them to hack your transmissions and even hijack your model, though I have seen it demonstrated but never heard of it actually occurring in the real world.

Clear channel selection:

The nature of the spread spectrum transmission techniques is such that reliable and recoverable data streams can be obtained even when the actual received signal has a bit error rate in excess of 99% but it cannot handle 100% errors or a permanent or long term loss of communication. Where the communication channel is not usable or the range of operation has been exceeded, the receiver and transmitter will initially continue to use the selected set of operating channels and channel usage sequence. This can actually allow for the two devices to re-establish communication easily and of course then use a revised channel selection list. If the loss of communication is permanent or has too greater a time period then the transmitter/controller will scan for a fresh channel list and then start broadcasting for its paired receiver. The exact channel selection behaviour of the receiver is vendor specific but some do a quick scan for a clear channel and just wait there whereas others scan for a clear channel from a set of HUNT channels and then loiter on one of those channels for the broadcast from its bound transmitter/controller. Actually the association methods are very numerous with some being quite rapid and others taking a little more time. The association broadcast is a very quick transmission and so channel changing rate can be very high and therefore the time to reassociate is quite small assuming that any channels are free to use.

Binding:

The binding process described herein is just a generic example so that you may understand the general idea behind the process. How it is actually implemented in brand X or Brand Y makes almost no real difference. It is notable that the bind procedure normally requires the receiver to be powered up in bind mode first. If the receiver was even capable of unsafe behaviour, if the bind plug was not fitted correctly, then I am sure that the safety warnings would be written around the bind plug being fitted correctly or the receiver bind switch being held securely. There are NO specific warnings of the dangers associated with the bind procedure and no unsafe or erratic receiver performances expected or warned against, simply because there are none.

Firstly the receiver must be placed into binding, (promiscuous mode) and this is accomplished by either a bind plug, a bind press button switch or is not required on some of the toys that boot up into bind mode. Regardless of how the receiver is placed in bind mode the receiver does the usual scan of the radio channels and then waits either on its hunt channel/s or across a small number of clear channels. The receiver is looking for a special bind request from the transmitter/controller or looking for an association request for a manufacturer default bind GUID. When the receiver receives the bind request broadcast of the transmitter/controller it responds with its own binding request, quickly stores the received GUID and waits for the transmitter/controller response. The transmitter should send an acknowledgement of the receipt of the receiver GUID and does so by including its GUID and the receiver GUID in the response. Now both the receiver and the transmit control revert to normal operation or wait for the bind plug to be removed for normal operation to be commenced.

Here it is wise to mention the boot up processes of both the transmitter/controller and receivers. When a transmitter/controller is turned on it must proceed through its boot-up sequence. The radio transmitter section is held disabled and the transmitter reads its non-volatile memory to establish what model slot was last used, its relevant radio operating characteristics, (for multiprotocol radios), and of course loads the its own GUID and the GUID of the bound receiver, (as per the bind information for the model slot). It then scans the control stick and switch inputs and then enables the transceiver module. The transmitter then scans the radio band and determines what channels are free to use and formulates a channel usage list.

Next the transmitter/controller begins its broadcasts to locate and start its communication session with the partnered receiver. A transmitter that does have not bound partner GUID often just transmits a default or NUL destination GUID and continues its search for the partnered receiver.

When a receiver is first powered up the microprocessor loads the GUID s of both itself and its bound partner transmitter/controller. It also does a scan of the radio band and establishes clear channels for it to use in waiting for the association request of its partnered transmitter/controller. It is important to know that until the receiver establishes communication with the partnered device the channel information for the control functions is greatly affected in that the throttle is minimised or disabled, (held open circuit), and will remain so until the receiver receives valid throttle data. The receiver will NOT apply any failsafe settings applicable to the throttle channel until after it has completed its boot-up sequence and of course then lost the communication stream thereby initiating a failsafe response. On some specific brand receivers the remainder of the channels are given centralised defaults whereas others are held open circuit also or have the failsafe settings applied.

Whilst the default control output values are actually unimportant for the majority of the channels the throttle channel is held WITHOUT any output, (that will allow the ESC to complete its own boot-up sequence). If an ESC was to get a actual throttle value other than minimum the ESC would simply enter Calibration mode and so the motor would still remain disabled. The receiver boot-up throttle output AND the ESC boot-up requirements thereby prevent any unsafe and dangerous operation of any devices connected to the throttle control output. MAJOR SAFETY FEATURE!

After the receiver has associated with its partnered device it will enable all control outputs and set them to the values received from its bound partner.

The actual binding process can give rise to some levels of confusion which can result in seriously dangerous operation. Firstly all receivers that support failsafe settings normally store them in their non-volatile memory as part of the binding process. Unfortunately not all manufacturers use a simple menu driven method of setting the failsafe values. Some use the actual control stick positions at the time the receiver is bound to determine the failsafe settings and have 2 separate bind modes for their receivers. The receivers claiming compatibility with such equipment supplied by non-OEM sources do not necessarily support both bind modes. For those receivers you need to consult the receiver manual for what failsafe versions it supports. If you get it wrong, the failsafe information will not be stored properly and may even become corrupted in the receiver memory. Often this can result in a failsafe setting for the throttle being set at maximum. Be warned!

Communication failure and “Failsafe”:

After the transmitter/controller and its partnered receiver have established communication and control values are being supplied to the servos, and motor control device of your model, there is the very real possibility of the communication being interrupted or even lost for a great period of time due to a lack of clear communication either caused by excessive distance, poor antenna alignment, or lack of radio channel availability.

Regardless of the cause the model is now on its own. You have a single last opportunity to command the controls to adopt a final set of positions and so these positions are best utilised for your safety and the safety of others. It is almost mandatory to minimise the throttle though with models using GPS I often activate the "Return to Home function" with failsafe. NEVER command any throttle setting other than minimum in a failsafe throttle setting. If you do not set a value for the throttle in failsafe or if the radio system has NO failsafe setting ability, the throttle output from the receiver will be open circuited on a LOS and the ESC will continue to use the last throttle setting received for about 10 seconds or so and then cut the throttle completely if no further information is received. The choice is yours, so chose wisely and then test the heck out of it.

I will include post flight handling in here as well as it will require an end to the communication between the receiver and the transmitter/controller. If your receiver has a properly set failsafe on the throttle control channel then by simply turning the transmitter/controller off the receiver will permanently disable the throttle by enforcing a minimum throttle value, (if properly set that is). Where your radio has no failsafe or it is not set just ensure the throttle is at minimum before the transmitter/controller is turned off and the receiver will either maintain the minimum or will open circuit the throttle and the ESC will hold the "Last received" setting, (minimum), until it disables the motor drive as part of its own failsafe settings. It is also wise to set and use a motor kill switch as another level of personal protection. Where your radio has no failsafe the throttle will just be open circuited and if you are using a servo controlled throttle device, (a servo on a gas powered model), then an external "Missing pulse" type detector device should be used so that the throttle servo is moved to minimum or off in the case of a loss of communication.

Other operating considerations:

As your radio control system uses a public band and there are many devices that also utilise the same radio frequency band, full band usage is going to be the exception and not the rule. Realistically in an urban environment a large number of clear radio channels can be difficult to find and the number will fluctuate wildly. You MUST be aware that your transmitter/controller can cease transmitting at anytime and the choice to transmit or not is NOT under your control.

When you are not using your transmitter/controller you should turn it off and thereby cease hogging the radio spectrum unnecessarily. Turning your transmitter off first will remove all possibility of a model motor start by design but only if your failsafe settings are properly set and for a minimal throttle setting. I have observed persons having severe control and Loss of Signal problems simply because almost every transmitter in the club was turned on, even when not being used to control a model. A case of the persons present actually generating the same "Interference" they are complaining about.

As the antennas we use on both the transmitter/controllers and on the receivers are simple and somewhat range limited, it is possible for two transceiver devices to attempt to transmit at the same time on the same channel due to the radiation "Null" points in their radiation patterns. Effectively no radiated power comes out of the end of the antenna and additionally 2 antennas at right angles to each other have difficulty communicating due to a massive coupling loss.

Even with CA it is possible for 2 or more digital radio control transmitters/controllers to transmit at the same time and over the top of each other. Simply put each antenna has a "No Radiation" zone attached to it and so it is possible to have the zones aligned between two transmitters when each transmitter checks for free channel before transmitting. This is rare thankfully but it is a distinct possibility. With a limited number of channels in the allocated operating band it is wise to remove any unused radio emission source that could cause a lessening in the availability of radio channels. When you are not using your transmitter you should simply TURN IT OFF. This will allow another radio system to use the channel and time slot that you would otherwise occupy and improve their chance of surviving any decrease in channel availability.

If a received signal does not match the receiver's GUID requirements then the entire data stream will be discarded and the receiver will enter "Sleep Mode" until the next Preamble, (synchronisation part of a data stream), is received. This is simple and as noise does not have a preamble or the matching GUIDs and definitely would not pass the error checking applied to all signals received NO 2.4GHz digital radio receiver will ever respond to noise or even a interfering or unwanted transmission.

Safety:

Firstly you should know and test what your radio will do. Never take anything for granted and NEVER rely on the continuation of the radio communication for your personal safety or the safety of others.

You should never carry a model that has its motor ARMED. For the motor to be armed, the receiver and transmitter must be in communication. It may seem obvious but a transmitter kill switch can be defeated and the throttle stick advanced easily. I have had to repair a fair number of different radio transmitters/controllers because of faulty control sticks and broken switches. Standard causes being the dropping of the transmitter/controller, Getting it wet, placing it on damp ground, somebody attempting to use the wrong unattended transmitter, someone stepping on or kicking an unattended transmitter, and of course the odd transmitter that gets thrown away when the new pilot panics because their plane is heading straight towards them on a collision course. Always test and use failsafe.

I recommend that you test your receiver by powering up the receiver first. The technology dictates that the receiver will not even complete its boot up and will definitely not enable the throttle control circuitry. I use this function to allow me, my students, and those who have a single handed operating requirements to be able to access and power up the model without any fear. It also allows the model with battery connected to be carried, (even by a person with a single hand), safely and without hazard.

After the model is in the area where it is to be pre-flight tested or to take off, the transmitter is then powered up and the normal testing and flying commence.

After the flight is concluded and any post flight taxiing is finished, I simply move the throttle to minimum, operate the motor kill switch, and then turn off the transmitter/controller. By doing this the motor in my model cannot start and so it is safe to carry it from the edge of the strip back to my pit area where the battery is removed and the post flight examination performed.

In the 4 years of my using the above model handling techniques in line with the single handed radio controller interface I have not had a single motor start that was not caused by my transmitter/controller command. My students over the same time have had the exact same results.

Additionally I do not place my transmitter on the ground, I do not leave my transmitter unattended and I do not drop my transmitter simply because I use a neck strap and always turn my Transmitter off when it is not being used.

What I use, teach and recommend is not revolutionary and if you think about it seriously it makes perfect sense. It the transmitter/controller is not powered on, the receiver open circuits all motor control signals or forces them to be held at minimum. If my transmitter has the wrong model slot selected when I first turn it on the receiver will simply do nothing. If my transmitter battery goes flat, the receiver just kills the motor for safety. My students now learn that turning off the transmitter effectively "Kills" a properly setup model.

Simply setup your models or drones to be disabled in the absence of the transmitter/controller control and your life and the lives of those around you will be far, far, safer.

If your model is not safe without the bound transmitter signal being present then you should not be using 2.4GHz digital radio equipment as it can cease transmission without warning and at any time subject to the congestion of the allocated radio spectrum.

Now there are a few extra things to be aware of.

In some older 2.4GHz digital radio control equipment designs the receivers have been known to seem to forget their bind information especially if the transmitter is not powered up first. This is a bit of a myth. The older designs use an earlier memory chip design that is susceptible to voltage spike corruption. A voltage spike that occurs at the wrong time can see the read of the non-volatile memory information, (bind and even setup information), corrupted and so then the receiver determines the memory corrupted and erases the stored information to correct the error.

ESCs do not have much filtering on the receiver supply voltage and the filtering effectiveness will degrade over time and with heat, so I recommend that students that suffer from the occasional loss of bind to fit additional voltage filtering. This same effect can be found where a model in flight can revert to having default set control channels when the trim is adjusted in flight simply because a voltage spike occurred at the same time as the channel trim information was being written into non-volatile memory. The sudden control reversal is always disastrous.

Again some older designs do not have the ability to disable failsafe and only support two types of failsafe setting. The throttle is controlled in both types of failsafe BUT the other receiver control channels are only set on one version of failsafe and held at the last position received on the other. This is not normally a problem, BUT not every receiver you may wish to bind to the transmitter supports both failsafe settings options. You need to know what the receiver can support in order to set any failsafe successfully. If you attempt to bind a receiver using a failsafe setting that it does not support the result can be unpredictable and can on occasion cause the failsafe setting obtained to be for a full throttle setting which is seriously dangerous. Always secure the model and test its failsafe operation after you have bound the receiver.

Here is a summary of things to I expect my students to remember for their safety:

1. Never accept anything as being safe unless you have proved that it is. It is your personal safety at stake and therefore you need to make your own informed decisions.
2. Where possible always configure a throttle kill switch on your transmitter/controller.
3. When available always configure failsafe on the throttle channel such that the throttle is set to minimum or disabled on loss of received signal.
4. Never have a model powered up and the paired transmitter powered up at the same time in the pit area. If you need to test something go to the run up or pre-flight area for the testing.
5. Never carry a model that has its throttle control activated, armed or enabled. Remember your transmitter can cease transmitting at any time due to the FCC Part 15C requirements so do not rely on it continuing to transmit for your safety.
6. Transmitter mishandling is a common cause of personal injury and if the transmitter is powered off it cannot cause unsafe operation.
7. Failsafe must be properly set or disabled. Improperly set failsafe is extremely dangerous and can inflict debilitating injuries upon you or others.
8. Either remove the propeller or disconnect one of the motor connections if you plan to reconfigure your model with the transmitter and receiver active.

9. Obtain and use a neck strap to prevent your transmitter being dropped and negate the need to place your transmitter down to carry a model using both of your hands.
10. Never place a transmitter on the ground as improper or inadvertent throttle operation due to corrosion or water ingress can be a short or long term result.
11. Never carry a powered up transmitter and powered up model at the same time. Juggling can cause control mishandling or you may drop and damage the transmitter, the model, or both.
12. Never place a powered up transmitter down whilst you carry a powered up model as the transmitter can fall or even be grabbed by someone else by mistake and then cause the motor on the model you are carrying to rotate under power.
13. Never power up your transmitter unless you are intending to use it immediately and always turn the transmitter off when you are not using it as this will reduce the incidents of spectral congestion causing other persons' models to crash or to otherwise lose control through a loss of channel availability.

Points to remember:

1. 2.4GHz radio control equipments can utilise any or all of the available allocated channels in normal usage. You have no control over the channels used as they are selected by the equipment dynamically. Each radio control transmitter and each receiver are actually transceivers which have both a transmitter and receiver within them.
2. When you bind your transmitter to a receiver, the transmitter sends its GUID, (Globally Unique Identifier), to the receiver and the receiver transmits is GUID to the transmitter. The exchanged GUIDs are stored in the memory of the devices and used to validate any transmission between them.
3. Both transceivers do not contain a legacy style MUTE function but rather utilise a sleep function which is used when the received input is not a valid and properly addressed transmission. With this simple fact it should be obvious that NOISE has no effect upon a 2.4GHz digital radio control receiver.
4. Where communication is lost the transmitter will rescan for clear channels and then search for its partnered receiver by transmitting on the clear channels in turn until re-association is obtained. The receiver will also quickly scan for clear channels upon loss of the communication for the re-association request signal.
5. The inability to communicate on a single selected channel is not a loss of communication but a loss is often declared after there are no clear channels available in the previously selected channel list for a number of full cycles of channel usage or hopping sequences.
6. The power of transmission within the spread spectrum transmissions is actually the sum of all of the power transmitted on each and every frequency transmitted as part of the emission. With wideband radio transmissions the available power is spread across the entire transmission and therefore can have a significantly lower peak transmitted power than that used in a narrow bandwidth transmission.
7. When receiving, the receiver effectively adds the power of the received signals on every frequency in the transmission and so the lower transmitted peak power is far less of a problem on a direct sequence transmission.
8. If your model is not safe without the transmitter being powered on and transmitting then it will never be safe due to the CA requirements of FCC Part 15C.