# 2.4 GHz Radio Control addendum

**Preamble:**

In the first article the requirements of FCC 15C and its effect upon the operation of the transmitter and receiver functionality was examined and the operation of digital radio equipment was explained in very simple terms.

I did receive a suggestion from one of the proof readers that I consider adding a section comparing the different safe operating requirements of both Analogue and Digital radio and as to why. So this addendum is a simple addition to the article with some basic safety information on both types of radio equipment.

**Analogue:**

Analogue radio equipment may have a radio mute function but this is not guaranteed and even an included feature, a very noisy radio channel environment may cause the mute to be defeated or lifted either repeatedly or even constantly.

As an analogue radio is promiscuous, (accepts and processes any signal that it receives), the normal safety requirement is to turn the transmitter on first and for the high level of the received signal to suppress any unwanted noise, interference, or on channel transmissions. This is where the "Tx on first" requirement first entered into the radio control safety handbook. The use of the term promiscuous is appropriate in that an analogue receiver is not paired to its transmitter and will respond equally to any radio control transmitter that is transmitting on the fixed radio channel the receiver is tuned to utilise.

IF you fail to turn on the transmitter first, the receiver will respond to any other signal that it can receive, noise, another local transmitter on the same radio frequency and even signals from the other side of the world including those using the frequency for voice transmissions.

I mentioned the sequential control slot operation of analogue radio equipment in the earlier article but I will elaborate a little further for those who do not understand the concept. The format of the analogue, (Digital Proportional), radio modulation was simple considering the current technology but it started with a pulse generator which would supply a single pulse every transmission cycle with a 20 millisecond interval to the next narrow pulse, (this was the frame rate and it could vary according to the number of control channels your radio was built to support). The reason for the long duration of the unused portion of the cycle was to allow for the sequential decoding of the transmission, (in the receiver), to achieve synchronisation through a timed receiver reset function.

The leading edge of the framing pulse was forwarded to the transmitter modulator, (which provided a narrow pulse for modulation of the transmitter output), normally causing the transmitter to generate and radiate radio frequency power, for the duration of the 350 microsecond pulse AND the framing pulse trailing edge was coupled to a string or line of timers, (monostable multivibrators). The first timer would then change its output state, (at the end of the framing pulse for a duration determined by the control stick and its trim setting combined, (nominally 1 to 2 milliseconds). When this channel timer expired it reverted to its initial state and its trailing edge was coupled to the next sequential timer as well as the narrow pulse generator for the transmitter modulator.

This coupling of the trailing pulse edge was coupled along the line of control channel timers, from 1 to 2, 2 to 3, 3 to 4, and so on. After the last control channel timer had reverted to its original condition there were no further edges or transitions coupled to the transmitter modulator the radio would cease to radiate until the sequence was recommenced after the long reset delay.

Please note that in order to save power it was the start and finish of each control channel/slot that was transmitted only. The above is just a simple method of generating the required transmission as I had built modulators, (40 years ago now), using on 2 cheap integrated circuits where one was a simple pulse generator and the other was a Johnson counter.

In the receiver the first part of the reception could be out of sync and cause a very small and short episode of incorrect channel information and so some receivers were subject to control channel output inhibition until after a full sequence time period had expired upon initialization. This feature was added to allow the receiver to synchronize prior to enabling the control channel outputs.

**Analogue radio safety:**

Whilst this type of operation was revolutionary in its day it had a large number of safety problems and also had special radio operating requirements for operator safety. The following are some of the operating requirements still applicable to the analogue equipments.

1. The radio transmitter MUST be powered on before the receiver and must remain transmitting until after the receiver has been powered off.

2. Transmitters were required to be held in a compound when not in use and the transmitters had to be identified by frequency flags or similar so that the chance of having 2 transmitters operating on the same frequency at the same time could be eliminated. This also included the use of a frequency board or the like as well.
3. The initial versions of throttle kill switches were added to transmitters to reduce the likelihood of an accidental transmitter throttle activation occurring.

**<u>Analogue radio hazards:</u>**

The hazards of using the analogue radios were numerous and I have listed a few.

1. Even if you were the only club member using the frequency other transmissions even from great distance could provide signals which the receiver would try to respond to. This is especially important during the control channel output timer period, (1 to 2 milliseconds) during which the transmitter was actually not transmitting!
2. If your radio flew too far it was possible for the control of your model to be taken over by someone else using a transmitter on the same operating frequency. (This was also referred to as hijacking).
3. Analogue radio receivers could also respond to radio and electrical noise if your transmitter’s battery went flat and your model could effectively go rogue and cause much damage and personal injury.
4. Even with your transmitter powered on a strong interfering signal could still cause severe control difficulties. This included electrical noise and even on

channel noise events like nearby storms or arcing electrical power installations.

5. Poorly maintained radio transmitters could drift towards an adjacent radio frequency and cause interference with another model's receiver as well as appear to suffer a reduction in operating range.
6. The selected radio band gave great range BUT this meant that a great distance was required between persons using the same frequencies. Radio control toys such as cars and the like could be in operation miles away and could cause you severe radio interference issues and the related issues of injury or property damage.
7. There was no FAILSAFE function and so the transmitter was used to suppress the possibility of interference causing throttle activation but this introduced transmitter mishandling as a problem.

Having said all of the above it is obvious that analogue users were rightly paranoid about the UNSEEN sources of problems with their cutting edge technology. It was left to the radio and electrical engineers to finally make radio control operation safe, (or as safe as possible). The following is the main differences in the 2.4GHz digital radio control equipment.

**Digital:**

As described in the previous article digital radio control systems now use spread spectrum radio modulation techniques, (also referred to as digital radio).

With the digital radios the transmissions are made across a far wider number of radio frequencies at the same time. (The radio channels are far, far, wider than those of analogue radio to allow for the transmission of much more information at a faster rate).

Each receiver MUST be bound or partnered with a transmitter for it to function. The receivers are definitely NOT promiscuous and will remain programmed to respond to only a single model slot on a single transmitter for as long as their memory is not corrupted or they are not rebound to another transmitter. Normally this is a permanent state.

A receiver will NEVER respond to any signal that is not from its partnered transmitter and does not contain its own identification number. Any corrupted radio signal received or that is not addressed to the receiver will NOT be processed as valid information. When first powered on, a receiver will fail to complete its boot up sequence until it receives a valid signal from its bound partner. This is a permanent firmware enforced requirement.

When a receiver is powered up it must complete its own boot up sequence, (including establish communication with its bound transmitter), before it enables the throttle channel.

**Digital radio safety:**

The following are some of the operating requirements applicable to the digital radio equipments.

1. Power up the receiver first! This allows the operator to fit the model battery, close up the model, and then transport the model to outside of the pit area where it can have its motor drive circuitry enabled by turning on the transmitter and the pre-flight testing can commence.
2. Always set and test failsafe properly. Failsafe should be set for minimum throttle level being applied in the absence of

a valid transmitter signal. Always test failsafe function before flight as a standard part of the pre-flight testing.

3. Always perform a radio range test prior to flight. This is a minimum requirement though telemetry systems reporting receiver signal level, noise level and bit error rate give more meaningful results.
4. If possible configure a throttle kill switch as an added safety feature and get used to using the kill switch as a safety measure. If a kill switch is not available then use the transmitter power switch to remove the risk of accidental model throttle activation by turning the transmitter off.
5. Upon landing and after taxiing the model to the collection area set the throttle stick or control to minimum. Then operate the throttle disable switch and turn the transmitter off. This totally removes the chance of a motor start and so the model is now safe for the model to be picked up and transported to the pit area where the model can be accessed and the flight battery removed.

**Digital radio hazards:**

The hazards of using digital radios are still numerous but relate directly to operator error, (a lack of technical understanding), and I have listed a few.

1. Turning the transmitter on first and off last. This arms the model at the very time you have your hands in the model trying to fit the model battery. It also requires you to not be in control of the transmitter controls which can and does cause inadvertent motor activation.
2. Turning the transmitter on first and off last can see some persons powering their transmitter up for the entire duration of their flying field visit, This simply increases the

number of concurrent radio channel users and in times of poor channel availability can actual cause other models to lose radio communication due to the CSMA requirements of FCC Part 15C.

3. The transmitter on first and off last does mean that a poorly setup model with a full throttle setting in failsafe can exist for many flights and only be discovered if the model leaves the flying area under full motor power or attempts to injure someone when it suffers any radio communication loss or interruption. Remember a transmitter can be powered on and adjacent to the powered up model and still suffer a loss of signal.
4. Unlike the earlier generations of radio equipment, digital radio control equipment uses microprocessors and can suffer serious issues if subject to moisture ingress or over temperature events. NEVER place a transmitter on the ground or leave it out in the open where direct sunlight can cause its internal temperature to soar. Never place a transmitter where it can be damaged or mistakenly used by another operator, especially if you have powered up models.
5. When using non-OEM receivers ensure that your setup is in line with the receiver manual and test the setup extensively before leaving the workshop.
6. Some older digital receiver designs require a very regulated and noise free voltage supply so where possible use proper voltage filtering, a separate BEC, or an ESC which has a greater current supply ability than the total drain of the model. The issue is simply that older equipment designs can suffer from memory corruption because of supply voltage variations or spikes. This can cause a loss of bind, a change in failsafe settings or even

control channel reversals because the receiver memory is reset after being determined as having been corrupted due to the effects of a voltage spike or supply noise.

7. NEVER continue to fly or attempt to fly any model which has a mechanical problem or a radio operating difficulty as these problems never resolve themselves. Radio operating difficulty can be a result of a lack of radio operating channels or a wrong protocol issue caused by attempting to bind the transmitter and receiver whilst the radio signal levels are excessive and causing the receiver to be effectively swamped with transmitter energy. For such radio issues in the field, (assuming the setup was completed and tested in the workshop), it may indicate a high level of local interference and so try again in 10 minutes or so. Do not attempt to fly anything that does not perform perfectly in the pre-flight test.

**Other technologies:**

Just a final warning! With the migration to stabilised models and flight controllers the actual safe radio requirements are becoming even more important, as is also your knowing and supplying the input requirements of the flight controllers themselves. Whatever you use or however it is setup you must test, test, and retest each installation or setup prior to leaving the workshop! This has never been more important as the electric powered models can swing a prop almost instantly and at massive power levels, (due to their rapid rise in torque). Make a single assumption and someone may lose a finger or worse, (and that someone may be YOU!). Electric models can and do BIGHT and they bight HARD!