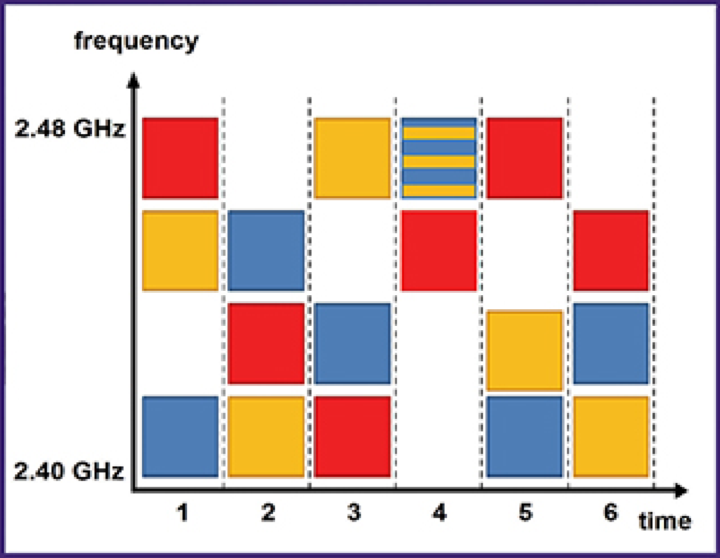
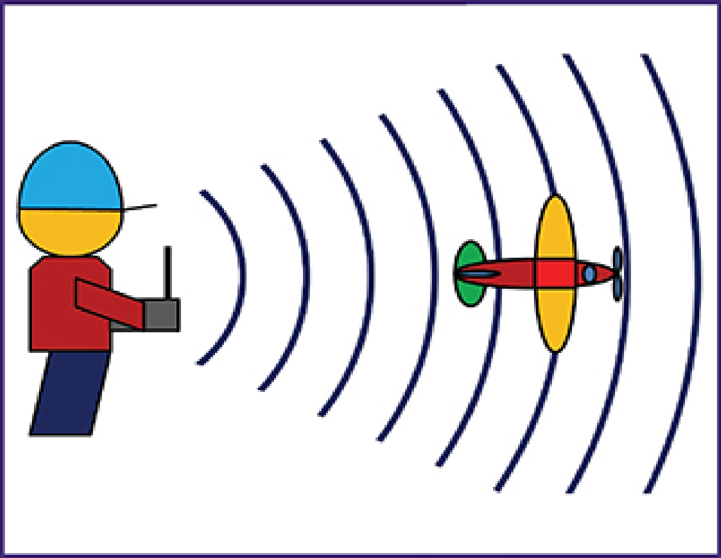
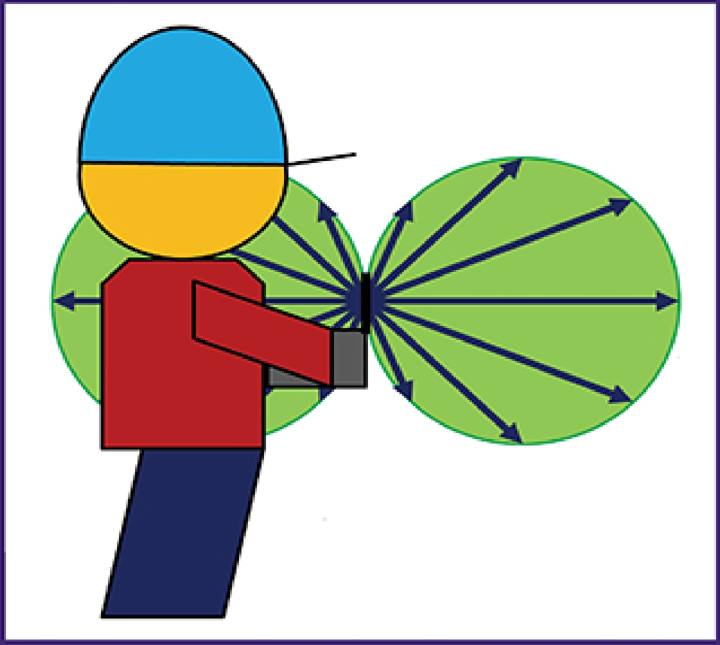
Roland Büchi

Radio Control with 2.4 GHz







Preamble

In the first years of the new millennium, in the development of radio control technology with 2.4 GHz, a real revolution has taken place. While the frequencies in the MHz range were standard over many years, a large proportion of modern communication technology and with it radio control (RC) has since taken the band between 2.4 GHz and 2.48 GHz. This development was possible not least due to faster transistors and today's microprocessor technology. The biggest advantage for the user is that he no longer needs to coordinate with others if he wants to switch on his radio control. All transmitters transmit on the same frequency band, and the receivers know through a sophisticated technology which signals are dedicated for them.

Model construction has been equipped with RC for over fifty years. Without it, this fascinating hobby would probably never have inspired generations of people. Without RC, especially the airplane, helicopter, car, and ship models would not have achieved such popularity. And this book is aimed primarily at the users of these types of models.

Of course there were many developments, especially with RC on the MHz frequency bands, which led to the technology used now. Since today almost exclusively 2.4 GHz RCs are sold, this technology is concentrated on in this book.

The components of a modern radio control, such as the transmitter, receiver, servos, and other peripherals, are discussed in a separate chapter. It is also shown here how the various units can be combined into a complete and functioning system.

This leads immediately to the range and its properties. On its own, this is not yet meaningful, because different factors such as obstacles, reflections, or the movement of the model itself can interfere with the safe transmission at 2.4 GHz. In addition, different antenna types with different characteristics are used. Their optimal alignment is also discussed on the basis of many examples. Many 2.4 GHz RCs operate with diversity, i.e. with multiple antennas. It is also specifically discussed here how the antenna orientations can be optimized in this mode. Of course some comparisons with the signal transmission in the MHz range are always made.

There is also a chapter on the modulation and transmission types. In many data sheets of modern RC terms such as PPM, PCM, ASK, FSK, PSK, FHSS, FASST, DMSS, or DSSS are found. The book is designed to help so that by the end the reader can classify and understand these properly and knows their most important characteristics.

The user interfaces of today’s RC are mostly two sticks. Each of them can be moved in all four directions. The stick allocations to the functions are clearly defined in the various models. However, there are several allocation modes. These are discussed, and a look into the future will also be made, with new concepts of user interfaces which may be capable of replacing the sticks. Rotary encoders, switches, and buttons are also discussed.

The data transmission is possible in both directions with the 2.4 GHz technology. This means that the receiver in the model can also operate as a transmitter and can transmit important telemetry data from the model during operation.

In doing so, the transmitter functions briefly as the receiver and may optionally display battery voltages, engine temperature, or currents of the model. An overview of the available systems is given.

At the end of the book are some practical tips on installing the system into the model, and for the interference suppression of components.

Contents

1. Introduction

The development of technical model construction has always been very closely linked with the development of radio controls. With ‘actual’ cars, airplanes, or boats, the driver, pilot, or captain sits inside. He controls them directly via sticks, steering wheels, brakes, accelerator pedals, throttles, etc. Since models in contrast are unmanned, they must be controlled from the outside. Since the radio control represents the only method of intervention to the models in use, it has become the most important aspect. Contemporary models of all types are getting larger and larger, and ever more powerful motors are being installed. The largest models sometimes cost as much as a midsize car. Their weight and speed also represent a significant safety risk. Only the reliability and capabilities of modern radio control systems allow safe maneuvers on land, at sea, and in the air.

Figure 1: Radio control system with all necessary components

Today, at the beginning of the 21st century, almost all commonly used RCs are based on 2.4 GHz technology. This is actually only a logical development of all previous transmission types. It is even so that the origin of many features of modern RC is several decades old.

1.1 Origins of wireless transmission

The birth of wireless transmission was approximately in 1864. At that time, James Clerk Maxwell predicted the existence of electromagnetic waves in theory. In 1886 the physicist Heinrich Hertz was able to prove this with measurements. Guglielmo Marconi could use them practically in 1901. He was able to send and receive wireless Morse code across the Atlantic Ocean.

Electromagnetic waves can propagate at the speed of light in vacuum and in the air. They can transport energy and also information from a transmitter to a receiver unit, without any wires.

First points of contact to model construction

As with many other technologies, model construction was one of the first applications here. Nikola Tesla, the genius in electrical engineering, made many inventions in various fields. At the world exhibition in New York in 1898, he presented a radio-controlled model boat. That was probably the birth of the RC in model construction. But another 50 years passed before RC became more common. The first transmitters, which sent in the MHz range, were sold in the 1950s.

1.2 From the MHz to GHz transmission

The range of MHz transmitters is in the order of several hundred meters to a few kilometers. It depends on the permitted transmission power. If two transmitters want to transmit their signals within the same area using the same frequency range, then the receiver can’t distinguish where the detected signal originates from. The received signals are then an overlapping of the two transmitter signals and it is not able to detect the proper signal.

The regulatory authorities therefore had to legislate for the use of frequencies. RC in model construction thus received its own frequencies in the MHz range. They are the only users of these.

The path to GHz radio controls

For many years from the 1960s to the 2000s, frequency panels dominated in model construction events. Before the model pilot or captain could switch on his radio control, he first had to mark his channel on the panel so that no one else would use it. Any other pilots with the same channel could not switch on their radio control during this time, not even for testing purposes. Here, the discipline of everybody was vital. Often transmitters were still switched on unintentionally. This was usually very bad, especially in model flight. More than a few models were brought rather rudely from the sky in this way.

There were also cheap RCs, which were very broadband due to technical imperfections. Thus they sent their signals on the neighboring channels in addition to their own. These could be identified only with special frequency scanners. The scanners were indispensable tools of the organizers, especially for larger events.

First 2.4 GHz RC

The development of microprocessors also influenced transmission technology. In modern communication technology, the band of 2.400 GHz to 2.483 GHz is very important. It belongs to the socalled ISM (Industrial, Scientific, Medical) band. RC became an additional application of it. At these 2.4 GHz frequencies, however, the RC is not alone. Unlike the MHz band at which a certain frequency range is reserved exclusively for them, the 2.4 GHz RCs must share this band with a variety of other modern means of communication. A popular generic term for this is WLAN, short for Wireless Local Area Network.

In the early 2000s, many 2.4 GHz conversion kits were sold for the MHz RC. Here, only the high-frequency part of the transmitter and the receiver had been replaced. The transmitter housing and peripherals such as servos and motor controller were still the same as before. However, it soon became apparent that the new technology had a decisive advantage compared to the old one: one was now no longer dependent on others not using the same frequency at the same time. One could therefore switch on one’s radio control at any time regardless of other users. For this reason, the 2.4 GHz RC replaced the old MHz RC almost completely within just a few years.

Biggest advantage of the 2.4 GHz technology

The many means of communication in the 2.4 GHz band transmit their data only reasonably free from interference when the transmitter and the receiver use the same encoding. On the other hand, they also need to change the frequencies at any time and know from each other which frequency is being used at the moment. This is just a simple summary of what is discussed in more detail in Chapter 5.

This coordination between the transmitter and the receiver is called binding. Essentially, it is what replaces the insertion of the quartz pairs in the transmitter and receiver in the MHz RC. Somewhat loosely, it can also be explained as: the binding is used to set the language between transmitter and receiver. Only if both understand the language can they speak to each other. If many people are in a room and all want to communicate with each other, then it works if the Frenchman understands only the French sentences and the Englishman understands only the English ones. It works even better if all speak at the same volume. So technically, no one should speak with more power than the others. This too will be discussed in Chapter 5.

In any case, this has the consequence on the airfield, the track, or the lake that one transmitter speaks French with its receiver while another one speaks English. In transmission technology there are an infinite number of these ‘languages’. And so it is (almost) impossible that in the same place two receivers and transmitters can’t understand each other because a lot of others are communicating with each other on the same frequency band.

2. Components of a radio control

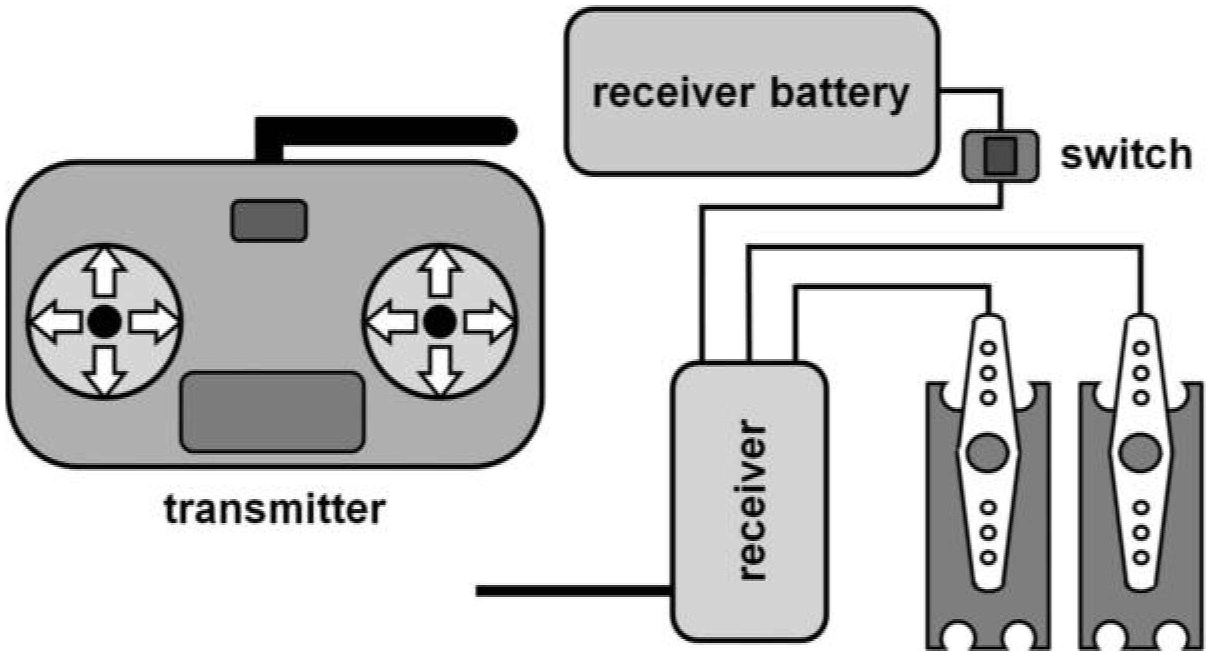


Figure 2: Schematic illustration of an entire RC system

An entire RC system consists of at least the components of Figure 1 in Chapter 1. In Figure 2, they are shown schematically. They are explained briefly here and will then be presented in more detail in the following subsections. On the left side the transmitter can be seen, and on the right side is all that is placed in the model. However, there are different ways to provide the receiver with energy. The version shown here is used for example in models with a combustion engine. Here, the receiver is powered directly with its own battery. Even if there is no motor, as with sailplanes, such a battery is required. However, the models are often driven by an electric motor. Then, the receiver is usually powered via the motor controller, directly from the drive or flight battery. So a separate receiver battery is not necessary. Such a configuration is shown schematically in Figure 3.

The servo is an indispensable element of the radio control technology. It ensures that the signals coming from the radio control cause corresponding actions in the model.

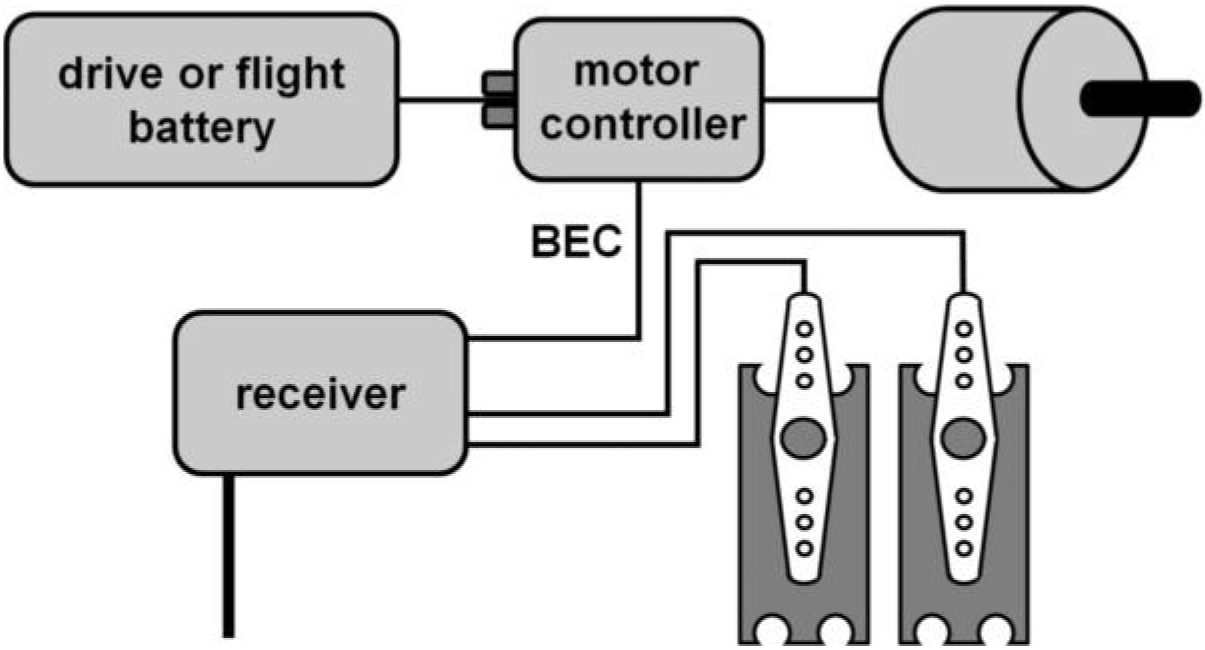


Figure 3: Schematic diagram of a receiver system, which is powered by the drive or flight battery

2.1 Transmitters

Handheld transmitter

The transmitter shown in Figure 4 is a so-called handheld transmitter. This is certainly the most common among all transmitter types. As the name suggests, the transmitter is held with the hands on both sides. Often the pilot controls only with his two thumbs, which are placed on the tops of the sticks.

Another method of control is to take the sticks between your thumbs and index fingers and clamp the transmitter with the palms. The author prefers this control mode, as it allows in his opinion a fine control. A strap that is worn around the neck can provide additional support. This offers the advantage that the transmitter cannot slip out of your hand and fall to the ground. But it has the disadvantage that it is sometimes cumbersome, for example during a throw start of a model airplane.

Figure 4: Handheld transmitter

Console transmitter

Mostly one controls with the thumb and index finger, while the hand is braced on the transmitter. The transmitter remains in position without the help of hands. For many handheld transmitters, extensions for console transmitters are available.

Whether a handheld or a console transmitter is preferred depends on the personal preferences of the pilot. Often it is the case that those who only need the four functions of the cross sticks prefer the handheld transmitter. If you need to control more functions, you have to operate different encoders or switches in addition to the two sticks. This is rather difficult with a handheld transmitter. Therefore, these pilots prefer console transmitters. Examples are large model airplanes or model ships, in which a lot of additional functions are often found.

Figure 5: Console transmitter

Colt transmitter

A very different type of control has become popular with RC cars and fast RC boats. This is the colt transmitter of Figure 6. A righthanded person takes the transmitter in the left hand. With his right hand he operates the steering wheel. The push button can be operated on both sides and is ‘gas’ while pushing, and upon retraction ‘brake’ or ‘backwards’. Both together can be implemented in the modern brushless motor controllers with one function or channel. Frequently, there is a third channel available.

This is designed for mechanical brakes. With a sometimes additional fourth channel, the front and rear axles can be braked separately. Thus, RC cars can be controlled more