A Brief Guide to Receivers

Today's radio control receivers are sophisticated examples of modern technology, but even so users often encounter inexplicable problems with them, especially when they are used in model aircraft. That's why this guide provides information which is of general validity, i.e. it does not refer to particular makes of equipment. In a sense we are doing some basic homework for you which other manufacturers, who have been in the market longer than us, should have done long ago. Our intention is to help any modeller with receiver problems to locate the fault and eliminate it in a systematic manner. We hope that in this way we can make a significant contribution to increased operational security and reliability of all models, and particularly of model aircraft. This is a practical guide, designed to be understood by anyone, and for this reason it may not always use expressions which are absolutely correct in the technical sense.

Introduction

The receiving system represents the connection between the pilot's control commands at the transmitter, and the control surfaces and other working systems in the model.

The transmitter and the receiver are linked by what may be termed the "transmission path". This cannot be seen or felt, and for this reason is often seen as "mysterious" by the normal user. It is essential that this link should be maintained, if the receiving system and working systems in the model are to work perfectly; if not, the model cannot carry out the pilot's commands in every attitude.

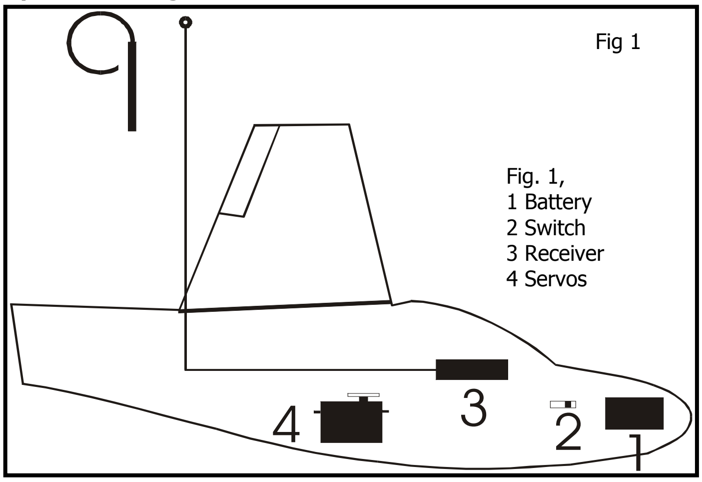
Many users assume that any make of receiving system, i.e. a radio control receiver and the servos connected to it, should or even must work perfectly in every model and every situation. Unfortunately the range of installation methods and other variables is so immensely wide that this is simply not a reasonable assumption. As a result crashes and failures repeatedly occur, although a high proportion of them could be avoided if the modeller had the appropriate background knowledge, and adopted the appropriate procedures.

Since the transmitter broadcasts its signal to the receiver using "RF" (Radio Frequency: high-frequency energy as used by ordinary commercial radio and television transmitters), the transmission path is invisible, i.e. it is not possible to assess it directly without further tests. It is the broad purpose of this guide to ensure that any modeller can check and assess the transmission path BEFORE flying the model, and without turning himself into an expert.

Arrangement in the model

The arrangement of the components in the model is of crucial importance if you want to avoid interference effects.

Optimum arrangement:



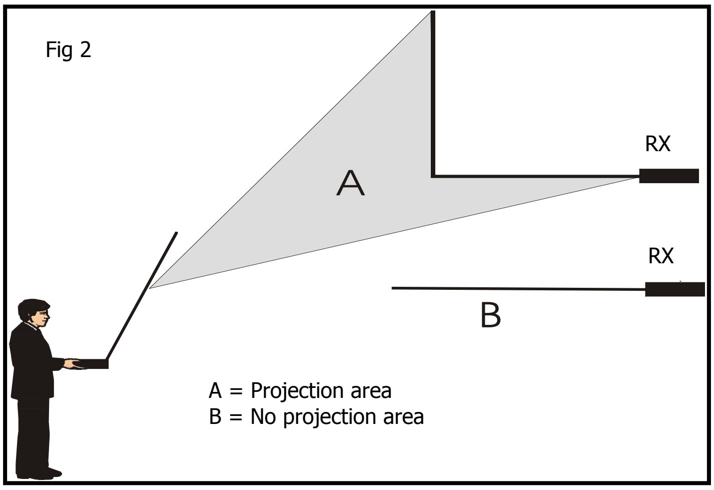
Radio system manufacturers assume this "most common arrangement", and their receivers are therefore designed and built to cope with it. Manufacturers are bound to settle on a particular standard arrangement, as it is not possible in a laboratory to emulate all the possible variations. Naturally, the producers try to design their products in a "tolerant" way, so that changes to the standard arrangement have no major effect, but they cannot guarantee to anyone that their receiver will actually work perfectly in all attitudes and situations which the user adopts for his model.

Every modification to this arrangement, i.e. pointing the aerial in a different direction, extending the servo leads, locating the battery directly adjacent to the receiver, placing the servos next to the receiver, installing additional devices such as gyros and all sorts of other items; all these things are capable of changing the reception characteristics in such a way that the model no longer responds in particular attitudes, and the operator loses control, even though the individual component parts may be in perfect working order. If the installation of the receiving system in the model generates a problem, the basic result is always the same: a reduction in effective range, or alternatively the occurrence of directional effects, which means that the receiver in the model encounters problems or so-called signal "black-out" when it is in certain positions relative to the transmitter. Sometimes the problem manifests itself at very close range, and disappears at a distance, when everything seems to work perfectly. Since range and directional effects are the problem, *testing radio range* (and *directional range* - see below) remains the best method of detecting and eliminating the problems. In fact, these checks should be carried out before the system and/or model is first operated. Radio problems usually show up as servos moving when they should not be moving, or the electric motor bursting into life unexpectedly. In many cases a slight modification to the installation of the receiving system, or in the deployment of the receiver aerial, eliminates all the problems at a stroke.

Deploying the receiver aerial

As a general rule you should be aware that each part of this section refers to an aspect which could lead to problems under certain circumstances, and these problems can be detected with a range check. Arrangements which we do not recommend may also work without problems in your particular case, and once again you can determine this with a range and direction test.

Whip aerials



The optimum type of aerial is actually the vertical whip (see Fig. 1), which is a vertical length of rod joined to a short horizontal length of flexible wire; at the same time the servo and battery leads should be routed as far away as possible from the receiver aerial wire inside the fuselage. Unfortunately the modeller is usually unable or unwilling to implement this arrangement, and this applies especially to model aircraft. However, it makes a good general point, which is that you must avoid any installation which allows the receiver aerial to point straight at the pilot in particular flight attitudes, i.e. the aerial is "end-on" to the transmitter (, see Fig. 2). This position produces the lowest field strength to the receiver input, and if other conditions of the installation are also less than perfect, you may well encounter problems. This can be avoided by ensuring that at least part of the aerial is deployed vertically, i.e. part horizontal, part vertical. The easiest method is to run part of the aerial away from the receiver horizontally, the rest standing vertical. The longer the vertical part, the fewer the directional problems which arise, and the slighter the effects of any imperfections in the radio installation.

Additional notes on aerial deployment

It is fundamentally essential to avoid the receiver aerial running parallel to servo leads or electrically conducting linkage wires.

Coiling the aerial, or leaving it in a tangle, must also be avoided under all circumstances, as the aerial works as if cut off short, producing a very considerable loss of effective range. The original aerial length (usually 90 cm - 1 m) must always be maintained. Shortening the aerial is not permissible except with model cars, where a range of only 100m is generally sufficient. Even then, however, don't just cut it to any convenient length: cut it exactly to half the original length, as this still gives a reasonable range.

Receiver aerials in model aircraft
Always deploy the aerial **as far away as possible** from servos, servo leads and linkage wires. The ideal is a whip aerial but, if this is not possible or desirable, tensioning it to the fin also works well. Deploying the aerial inside the fuselage is permissible (see below), provided that no steel wires or other electrically conducting servo leads or linkage components run parallel to it. Note that carbon fibre in the fuselage has a shielding effect, and in this case the aerial must be deployed externally, ideally a long way from the fuselage, as the fuselage itself will have a shielding effect when the model is in particular positions.

If the aerial is tensioned to the fin, then it is certainly permissible to allow the end (10cm long or more - see Fig. 3) of the aerial to trail loosely. This again avoids the danger of the whole aerial pointing straight towards the transmitter "end-on", with the problems described above. In this case you should fit a "strain relief" where the aerial passes through the fuselage; ideally a small piece of silicone sleeve (fuel tubing).

If you are a model glider pilot, and think that the aerial cannot be tensioned to the fin due to the increased drag which it incurs, we suggest that you take a look at the jet flyers and how they deploy their aerials: they use *whip aerials, and accept the increased drag*. Our view is quite straightforward: you should deploy the receiver aerial in a way which reflects the model's value to you. We think that any of our models is worth such a lot that we are glad to accept the higher drag. The increase is unmeasurable, but must be slight; so we deploy the aerial outside the fuselage, running to the fin. On the other hand, maybe we don't fly well enough to be able to detect this immense drag.

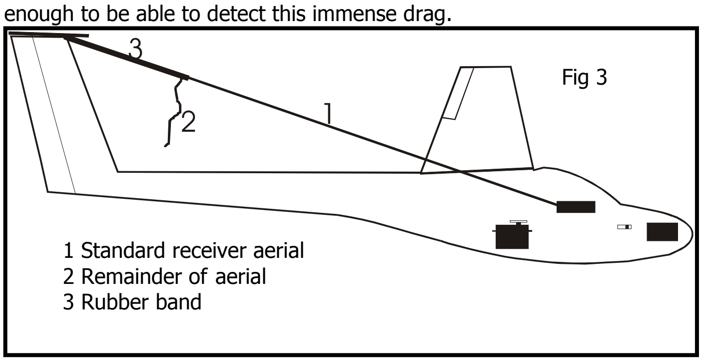


Fig 3

Deploying the aerial inside the fuselage
It is also possible to install the aerial in the fuselage, but this can lead to problems, depending on the exact arrangement. Running the aerial straight down the fuselage is often recommended, but in our experience this regularly leads to directional effects and/or receiver "black-outs". This tends to happen precisely at take-off, when the receiver aerial is "end-on" to the transmitter (see Fig. 2). The problem of "end-on" aerials should always be considered when performing a crashed model's post-mortem. We have often seen crashes which take this form: the model takes off and climbs away, then suddenly heads violently for the ground. The pilot pulls out equally violently, and the wing fails with catastrophic results, even though the model was initially at a safe height. The cause? The position of the receiver aerial, perhaps exacerbated by the pilot pointing the transmitter aerial at the model; the receiver is very likely to "black out" under these circumstances. A random servo movement is the result, and the model dives; reception is then resumed, hence the model's reaction to the pilot's panic "up-elevator" response. Such a sequence of events is not generally considered when trying to establish the cause of the crash.

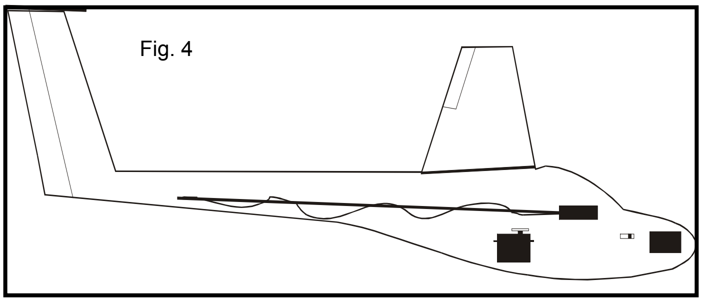


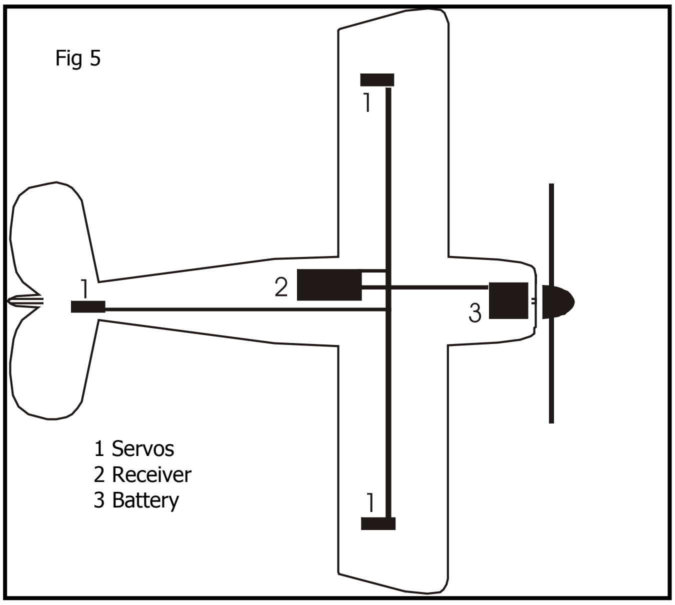
Fig. 4

For this reason, deploying the aerial in a gentle curve inside the fuselage is much better than in a dead straight line, as this produces fewer directional effects.

Our solution is to take a length of balsa strip or beech dowel, fix the aerial to one end and lay both loosely in the fuselage. The aerial now lies loosely in the fuselage, but cannot get tangled or bunched up. This method also eliminates the tiresome task of persuading the aerial to slip inside the plastic sleeve.

Interference factors
If you encounter problems in using your equipment, or you detect a problem during a range check, you should consider the following factors, all of which can tend to produce interference.

Directional effects / long cables
Although manufacturers design their receivers as far as possible to prevent RF signals entering the circuit through the servo inputs, any cable which is connected to the receiver's servo inputs also tends to act as an additional aerial. However, the receiver is only tuned to match the standard aerial, so any signal these "additional aerials" pick up takes the form of interference (Fig. 5).

Fig 5


Nevertheless, servo leads have little effect provided that the cables are no longer than normal servo leads, the battery is located in a sensible position, and the aerial is deployed a long way from the servos and servo leads; the receiver is designed to cope with this situation (see above). However, the RF entity which we call a "receiving system" is modified by its installation in the model, and there can be adverse effects, especially if the cable lengths are half the length of the aerial (usually 45cm), the full aerial length (90cm) or even longer than the receiver aerial. The same applies to battery leads and switch harnesses. The rule is simple: **the shorter the cable, the better**. Particularly problematic in interference terms are cables running out to both sides to the wing-mounted servos, or a lead running to a rudder servo mounted at the tail. If this runs parallel to the aerial, running back to the fin, you can expect trouble. These situations often create interference, and the cables may also tend to shield the receiver aerial from the transmitter signal, with the result that we experience directional effects. Bear in mind that cable lengths are cumulative; for example, 2 x 45 cm produces 90cm, which is the critical length for interference.

Field strength fluctuations
If the aerial is allows to swing about in the air behind the model, the field strength at the receiver aerial input will fluctuate widely. This can be difficult for the receiver, although modern circuits are very good at handling such problems; even so, you can make the receiver's work easier by avoiding such fluctuations. That is why we recommend whip aerials, or some other method of stiffening the trailing aerial.

Extending cables / fitting suppressor filters
As a general rule you should ensure that all cables are kept as short as possible. Leads should always be arranged neatly and tidily in the model, and never in a confused heap, crossing over each other. We hope it goes without saying that the leads must not be under tension when connected to the receiver, otherwise there is a good chance of them pulling out in flight.

All leads connected to the receiver must be considered as potential problem areas if you encounter radio problems. This includes servo leads, extension leads, switch harnesses, programming leads; in fact, everything that is connected to the servo sockets, including gyro leads etc.

If you must extend connecting leads, we recommend the use of twisted cables. There are also many suppressor filters on the market, but in our estimation these often have little effect, although there are probably some makes of receiver which do respond well to suppressor filters when extension leads are in use. In any case, suppressor filters never do any harm.
In large-scale model aircraft separation filters are a must, as every possible reserve of safety must be built into the model. Separation filters should feature ferrite rings, with the cables wound through them.

In our experience iron rings, through which all the cables are passed together in a bundle, have ZERO effect. In their standard application these units are designed to prevent cables radiating interference.

Aerial length / whip aerials
The basic rule is this: the total length of the receiver aerial must always be the same as the original aerial. In the case of ACT receivers this is 90 cm. 2 or 3 cm either way is not important.

As already mentioned, a whip aerial is always the best solution. This consists of a steel rod mounted vertically on the model, connected to a flexible wire deployed inside the model and running to the receiver (Fig. 1). If the whip aerial (steel rod) is 60 cm long, the remainder of the aerial wire should be 30 cm long. The steel rod should be sufficiently stout to keep it stiff in flight, i.e. it should not sway to and fro. Be sure to form a loop in the end of the rod to guard against eye injury. The joint between steel rod and flexible wire must be soldered competently; the solder joint itself will be brittle, and this area must be protected from vibration, e.g. by a piece of heat-shrink sleeve. Check the soldered joint at regular intervals.

Switch harness / battery
Many products in these categories are available with very long leads. Here again, check that the cumulative cable lengths are not critical, as already described. If possible, shorten the cables. Long battery leads also limit the maximum current flow, so you should also ensure that conductor cross-sections are adequate (see below). The shorter the lead, the lower the resistance, the higher the possible current flow, and the lower the voltage drop.

Electrical "noise"
"Noise" always occurs when metal parts rub or vibrate against each other. The vibration tends to generate static charges, and these charges are dissipated by sparks jumping between the metal parts. These sparks usually contain RF energy, which interferes with the receiver. This form of interference occurs in particular with model helicopters and fixed-wing models powered by internal-combustion engines. Although most modern receivers are very efficient at noise rejection, remember to check for this if problems arise; it is sound practice in any case to exclude electrical noise as far as possible.

Electric motors
Electric motors generate intense levels of high-frequency interference. Brushed electric motors pass high currents to the rotating commutator via the static brushes, and this process generates high-energy sparking. The sparks contain high-frequency energy which is a powerful source of interference to the receiver. However, the interference is not only emitted by the motor itself; the power leads to the motor and sometimes even the battery itself also radiate serious interference signals. The radiated interference can never be eliminated, and the only way to reduce it is to suppress the motor. For this reason battery leads, motor leads, and every item which carries high currents and is connected to the motor in any way, must never be installed close to the receiver or the receiver aerial. Keep these sets of components as far away from each other as possible.

BEC power supplies
It is important to note that many speed controllers, including high-quality brands, pass pulsed interference to the receiver via the power supply (BEC) lead. Since speed controllers vary motor power by pulsing the current, it is obvious that this cannot always be isolated 100% from the BEC power supply. Not all receivers are susceptible to this, but it is a potential problem to be aware of. If you encounter interference, but the problem is cured by fitting a separate receiver battery, the cause is the BEC circuit of the speed controller.

Engine ignition systems
This is a difficult subject, as ignition systems may conceal many sources of interference which cannot all be "grasped" or "seen". Spark ignition, based on a spark plug, generates high-energy interference which may be on any frequency, and is radiated by all components connected to the ignition system. This applies in particular to the plug cap and ignition lead, which absolutely must be suppressed and earthed. Faults can easily be present under the insulation of the ignition lead or plug cap, and this may cause sparks to occur at the "wrong" places. These may have no adverse effect on the engine when running, but generate serious interference to the receiver. The only way of detecting this is to carry out a range check with the engine running.

If you have an electronic ignition system with a separate battery, the battery must be installed as far away as possible from all the radio control system components - including the receiver battery. The ignition battery is subject to the interference peaks generated by the ignition system, and these are radiated in turn by the battery and its connecting lead. For this reason the ignition system must never be powered by the receiver battery. Ignition interference problems are difficult to track down, and the remedy is usually only found by systematically replacing the components.

Additional receiving system devices
Every supplementary unit, including gyros, battery monitors and the like, involves additional cables, with the potentially adverse effects already described. To avoid problems, these items must also be tested. An additional source of interference is the micro-processor on which many supplementary devices are based. These operate at a fixed frequency (clock frequency) determined by a quartz crystal, and therefore generate very low-level RF radiation at the clock frequency. This generally has no effect on the receiver provided that the manufacturer selects a clock frequency which does not coincide with the reception frequency range of the receiver, or a harmonic frequency of it (a multiple of the base frequency). This is usually the case; at least, our ACT gyros are all designed in such a way that no harmonic of the clock frequency can interfere with any possible model receiver frequency.

Nevertheless we offer the usual advice: maintain a certain distance between the receiver and any auxiliary device, as this will at the very least ease the work of the receiver.

VHF transmitters
These can certainly cause interference on our 35 MHz frequencies, although they do not transmit on 35 MHz. How can that be??? RC receivers feature what are known as harmonic frequencies and adjacent frequencies. Our receivers work by superimposing frequencies, and filtering out the information signals which are contained in the RF signal broadcast by the transmitter. An Intermediate Frequency (IF) is always superimposed; in the case of single-conversion radio control receivers the IF is 455 kHz. That is why the legend on the receiver crystal is not quite what you expect: it is usually the transmitter frequency minus the IF. Example: channel 66 = transmitter frequency 35.060 MHz. Deducting the IF (455 kHz) produces the (printed) receiver crystal frequency of 34.605 MHz. When the IF is superimposed, frequencies are generated in addition to the desired mixed frequency, and these correspond to a harmonic of the base frequency, e.g. with 35 MHz it may be 70 MHz (35 MHz x 2) or 105 MHz (35 MHz x 3).

In Europe VHF transmitters work on 105 MHz, some of them extremely powerful. If we operate close to a VHF transmitter, flying a model fitted with a single-conversion receiver (as opposed to dual-conversion types), superimposed frequencies are generated on one "harmonic". The single-conversion radio control receiver then superimposes the signals from the VHF transmitter via its adjacent frequencies, and this can result in interference with the radio control transmitter signal.

One can avoid this problem by using a dual-conversion receiver. These units carry out a dual superimposition, or conversion, process, enabling them to filter out the interference from VHF transmitters. A further theoretical advantage is that a cleaner signal (less noise) is generated, which can further improve reception characteristics. In practice - and that must always be the deciding factor - even our simplest receivers have proved to have an exceptional performance even when extremely close to a VHF transmitter. When VHF transmitters are close by, there may be other technical characteristics which complicate the situation.

There is an easy method of determining whether a VHF transmitter can cause interference to a radio control system operating on a particular channel, and that is to carry out a simple calculation.

Let’s assume we wish to transmit on channel 66 = frequency 35.060 MHz. The receiver frequency is therefore 34.605 MHz. We multiply 34.605 by 3, giving a result of 103.815. This now gives two possible VHF frequencies which may cause interference: “plus IF” and “minus IF”.
If we now deduct our Intermediate Frequency (455 kHz) from 103.815, we establish one problematic VHF frequency for “minus IF” of 103.360 MHz; if instead we add our IF, we establish the other problematic VHF frequency of 104.270.

These two frequencies may cause interference to the radio control receiver. Unfortunately range checks on the ground only give results of limited usefulness, as the interference may have a more powerful effect when the model is in the air.

If you do the same calculation for 40 MHz receivers, you will see that there is no VHF frequency which can cause interference to a 40 MHz receiver.

Almost everyone has a car radio with a digital frequency display. Tune this to the frequency which could cause interference. If a powerful VHF transmitter is working on that frequency, you should not fly a model with a single-conversion receiver at that location.

If the digital display of the radio only features one digit after the decimal point, set the display to 103.3 for interference frequency 1 and initiate a slow station search. If the radio fails to pick up a station before the last digit of the display changes, there is no danger. This is a useful method of guarding against interference at unfamiliar flying sites.

In the immediate vicinity of VHF transmitters other potential sources of problems also have to be considered, amongst them direct interference caused by the transmitters’ high power. This problem arises if the length of a conductor on the receiver circuit board corresponds to the wave length of the interfering station; a cable in the receiving system may also have precisely the “wrong” length. This cannot be foreseen, and the only sure way of avoiding the problem is to forgo flying in the immediate vicinity of powerful transmitters. This point is only mentioned here because it is often forgotten at post-mortem time after a crash. The same also applies to radio relay stations; flying through a relay beam is usually regretted subsequently.

Signal : noise ratio
This is a term commonly used in RF technology, and actually means the difference in strength between the wanted and the unwanted signal.

In this case the term “signal : noise ratio” means that we must strive to keep the sum of all possible interferences as small as possible, in an effort to ensure optimum reception characteristics under all operating conditions.
Now, there are sources of interference which cannot be eliminated because, for example, the model’s design does not permit it; a good example is wing-mounted aileron servos with long leads, or a spark-ignition engine. In such cases all we can do is attempt to eliminate every other, avoidable, source of interference, in order to keep the signal : noise ratio as favourable as possible.

All these possible sources of interference may make you wonder how we ever manage to fly safely, but the information is not meant to make you anxious unnecessarily. We just hope that you are now able to appreciate the wide range of factors which can have an adverse effect on the working of a receiving system. Knowledge is the key to eliminating problems, and promoting safe radio-controlled flying.

Additional tips

Two or more receivers
One method of avoiding long cables in large-scale models is to consider installing multiple receiving systems, completely independent of each other. For example, one receiver and power supply for the left-hand half of the model, one for the right; or a separate system for the motor etc. This is a fruitful area for your imagination, although there are safety aspects which should certainly be pondered upon. We don’t wish to add to the discussion at this point, as our contribution could only be one more opinion to add to many. Like all the others, this would only be a personal theory, and we could not provide proof.

Battery switches (battery backers) / connector systems
Here again we have long cables ...., see above. There are certainly situations where a battery backer makes sense, but if you opt for one, do remember: short leads, please. In our opinion the most sensible battery backers are those which provide facilities for separate receiver and servo batteries. The reason for this is that the interference caused by the servos themselves is kept away from the receiver. This takes the form primarily of voltage fluctuations, which occur every time a servo is stalled, or hits its stops. Modern high-power, high-speed servos draw heavy currents which the battery cannot supply quickly enough via the cables, i.e. the voltage fluctuates. The receiver then has to compensate for this fluctuation, which involves extra effort for the software or electronics. Separate power supplies significantly reduce the workload for any receiver, i.e. they improve the “signal : noise” ratio.

The connector systems currently popular undoubtedly represent a current limiter in this respect, and this problem is crying out for a solution. If you connect five fast, powerful servos to the standard sockets on the receiver, and then assume that all that potential power is available, you are being blinded by the advertisements. In our view any manufacturer who claims that digital servos on their own, i.e. without an appropriate power supply, are the answer to the modeller’s prayer, and without even mentioning its necessity, should be viewed by the end-user with severe mistrust; we include so-called “reporters” in our list of suspects, too.

The JR UNI-connector system is an excellent, practically proven design, but the maximum possible current for the contacts is 2 Amps. MAXIMUM - no matter how fat a cable you use - the bottleneck is the contact itself. Therefore if you connect five servos directly to the receiver, and each servo draws a start-up current of 2A (or more), and the battery is connected by a **single** connector, you cannot assume that the full power of the servos is available. The only solution is a separate power supply for the servos, or multiple battery leads to the receiver sockets.

A major advantage of the JR UNI-connector system is that the positive (+) terminal is in the centre. If any connector is plugged in the wrong way round (180º offset), this will have no adverse effect, i.e. no damage will be done; the servo or the receiver will simply not work. However, if you plug the connector in offset to one side (only two of three pins on the contacts), reverse polarity and short-circuit could occur. Futaba and JR/Graupner use the same plug, although the Futaba version features a small external lug which provides additional protection against reverse polarity. This can be removed (with a knife), and the Futaba plug then fits in a JR socket.

Crystals
Of course, crystals are delicate components. They are naturally sensitive to vibration, as quartz is brittle. Crystals are temperature-sensitive, and the raw material has a temperature-dependent frequency range defined by the tolerance approved by the manufacturer. For this reason our Hyper-system crystals are packed in a resilient, rubber-like heat-shrink sleeve which damps shock-loads. The crystals made for us always feature the best gold-plated contacts, and are temperature-resistant within the range -15 to +50°C, i.e. the usual range for modelling. As such they differ from many crystals currently on the market.

Please note that our crystals also work in other manufacturers’ receivers. Just as other manufacturers’ crystals work in our receivers and also amongst each other, incidentally !!

Even today many manufacturers still claim that their receivers should only be operated using “genuine crystals”, but we believe that this is just a feeble attempt to under-estimate their customers’ intelligence. A comparable claim would be for a car manufacturer to state that his vehicles would only work when fitted with round tyres, knowing full well that all the others have round tyres, too.

Almost all of today’s receivers share the same internal electronic circuit, i.e. the same IC. This means that the same type of crystal is required. We have had all the “genuine crystals” analysed by specialist crystal manufacturers, and have established that the specification required for correct operation is always the same. For this reason we are happy to guarantee that our crystals work with other makes of receiver.

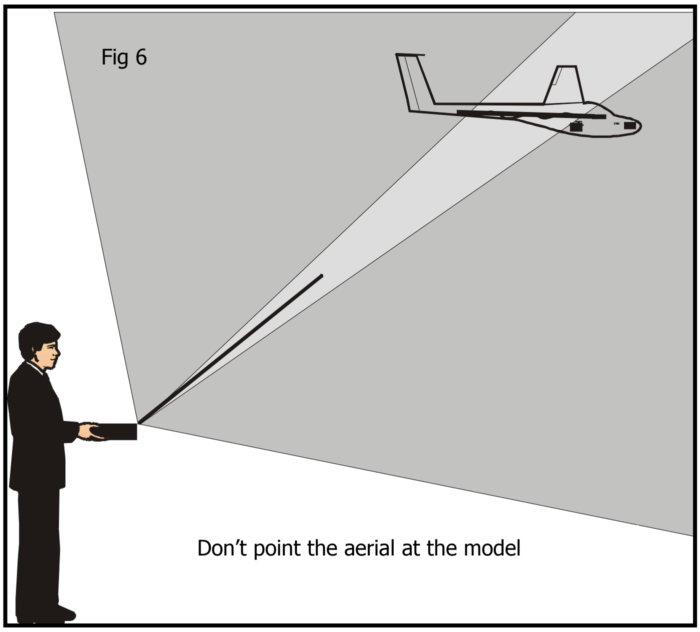
Transmitter crystals
Not so with transmitter crystals! You should always use crystals made by the transmitter manufacturer; it is not permissible to swap them over here. Transmitter crystals differ from make to make.

Vibration protection
Modern radio control system receivers are today manufactured using SMT (surface mount technology) methods - at least, that is true of all ACT receivers. This means that the electronic components are very small and not susceptible to vibration damage. Nevertheless, every receiver also contains components which have to be protected from vibration. For this reason you should always pack your receiver in soft foam. Never glue it in place or wedge it in its compartment with styrofoam.

Aerial wire colours
At a very early stage, when the then new frequencies on the 35 MHz band were allotted, frequency band colours were also laid down. For this reason the flexible wire aerials for receivers should be the following colours:
27 MHz receiver = brown;
35 MHz receivers = red;
40 MHz receivers = green.

Transmitter radiation pattern

Fig 6

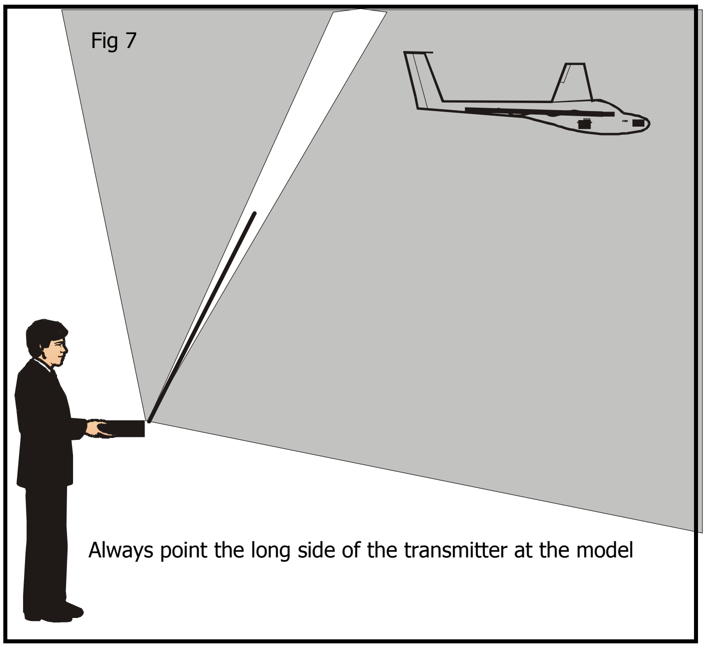


Don't point the aerial at the model

All types of aerial have particular radiation characteristics, so it follows that our transmitter aerials work better in some directions than others. Clearly it is always better for the receiver to pick up maximum field strength, as interference factors (see above) within the model are easier to suppress if the field strength is high, than if the signal from the transmitter is weak. This simply means that the pilot should always ensure that his transmitter aerial is aligned with the model in such a way that maximum possible power reaches the receiver.

If a standard telescopic transmitter aerial is used, the radiation pattern shown in Fig. 6 applies. This is a broadly panoramic characteristic whose only drawback is a very weak signal directly along the line of the aerial; for this reason you should never point the tip of the aerial straight at the model, as the receiver picks up the feeblest signal at such times.

Fig 7



Always point the long side of the transmitter at the model

In practice this means that the pilot should always stand with the **long side of the transmitter aerial pointing at the model**, i.e. to achieve optimum reception the aerial should point off at an angle to the model.

In contrast to the standard aerial, a short (helical) transmitter aerial has a strong directional pattern combined - in some cases - with slightly reduced range. This means that it is actually better to point the aerial at the model, although pointing the aerial down at your glider at the bottom of a mountain valley, as a downdraught sucks it ever lower, may cause you some excitement (and exercise).

Adjacent channel interference
In fact these problems should never arise, for all receivers on the market are designed for 10 kHz channel spacing, which means that the receiver works without problems even when all adjacent channels are in use at the same time. We know of no receivers which do not fulfil this requirement, with the exception of many slow-fly types. These are generally advertised as offering "full range", but many manufacturers seem to think this is 300 m or 500 m; in any case, these receivers do not work at 10 kHz channel spacing (see below).

However, if you experience adjacent channel problems, there may be any of a number of reasons:

1. The pilots may be standing apart, instead of in a group. Example: club sessions of aero-towing. This type of operation may well present technical problems, as it is basically essential that all pilots **MUST** stand together in a group. This is also possible with aero-tow flying, although it may be inconvenient.

This is the reason: if the distance from the model to "its" transmitter is, say, 100 metres, and the distance to the adjacent channel transmitter is 10 metres or less, then this represents an interference : use ratio of 10:1. This is the standard limit with virtually all receivers - even high-quality types, and no manufacturer can guarantee reliable operation of his equipment in such a situation.

2.) High power emissions. In the example above another possible problem may occur: another transmitter operating two or more channels away, rather than on the adjacent channel, may cause interference to your model at close range. In fact this is more likely to be an overload rejection problem rather than adjacent channel interference. In this respect there are wide variations between the receivers currently on the market, and there are equally significant differences in the radiated power of individual makes of transmitter (mentioning no names).

In any case you can always avoid both problems described here by requiring all pilots to stand together in a group, and **NEVER** flying your model directly above the transmitter aerial (i.e. the head) of another pilot.

Full range / slow-fly receivers
Slow-fly receivers are heavily advertised, but you usually get very little technology for your money. Full range - what's that, anyway? In our terms it is at least 1000 metres when a transmitter on an adjacent channel is switched on. You may think that a receiver with a stated range of 500 m is good enough for general flying, but you are in for a nasty surprise when your model crashes just 50 m into the flight on a club flying day, when several transmitters are also switched on. Every additional transmitter reduces the effective range of your system, and this applies in particular to receivers which - for reasons of weight saving and economy - are of unsophisticated design. If the manufacturer omits RF filters - and this is the only way to save weight cheaply - he saves money, weight and effort, but he certainly does not produce a better receiver. In our opinion this philosophy can certainly be dangerous, and that is why even our Micro6 receiver offers full range (by which we mean 1000 m) with full adjacent channel rejection. And did you know that typical slow-fly motors are generally serious sources of interference? With that in mind, cutting down on the technology is by no means sensible, and may even be hazardous.

There are also micro-receivers made by renowned companies which are fitted with so-called micro-crystals, and apparently these are only available at 20 or 30 kHz channel spacings. This is not because micro-crystals are only made on these channels; it is perfectly possible to order any crystal frequency you like, even at 2 kHz spacing if you really need it. No, the reason is simply that these receivers can't cope with direct adjacent channel operation, although this is not mentioned anywhere. Instead of informing its customers, the manufacturer attempts to solve the problem by offering a limited range of crystals, and acts as if other makes of equipment and other models operating on adjacent channels do not exist at all. So what do you think happens if your friend is flying a slow-fly receiver at a club session without being aware what his receiver can manage - or rather can't manage??? We are sure that modellers who suffer crashes due to "slow fly" receivers will invest their cash in other makes of equipment in future.

Receiver operating voltage
ACT receivers - and most other makes - work perfectly with 4-cell (4.8V) or 5-cell (6V) batteries. However, a 5-cell pack may produce up to 8 Volts briefly when fresh off the charger, so it is important to check with the receiver manufacturer that this is acceptable. Whether 5-cell batteries make sense is a moot point; they offer no advantages to the receiver, and servos don't necessarily work better, either. Admittedly, many manufacturers state servo output power when operating on 6 Volts, although the same manufacturers do not recommend the use of 5-cell packs (6V) with their receivers. Does that make sense? The reason is obvious: better torque figures sound better in the advertisements. Receivers of sensible design also work with 3-cell batteries, and this provides useful protection from momentary voltage collapse, or even failure of one cell if you are using a 4-cell battery. However, there are differences between makes in this respect. Most servos still work on 3 cells; they just run slower. For this reason, if you notice your servos running more slowly than normal, don't fly! Re-charge or check your batteries first.

Power-on sequence
First switch on the transmitter, then the receiver. Why?? Because this sequence avoids the situation where the receiver is switched on without a transmitter signal. Without a transmitter a radio control receiver picks up just about every RF signal which may be "buzzing around", as a fellow-modeller recently described it. This means that the servos may receive uncontrolled signals and run to their end-stops (causing gearbox damage), speed controllers cause motors to burst into life, etc. For example, if you prepare an electric model ready to fly, connect the flight pack and then switch the receiver on without first switching on the transmitter, you may find yourself going home with one or two fingers missing. When switching off, reverse the sequence: first switch off the receiver, then the transmitter. Here is an example of what may happen if you neglect this: your electric model has landed, but you switch off the transmitter first; the model is still on the ground, but the motor could easily burst into life. However, the propeller cannot turn, the motor stalls and overheats, and a short-circuit results. Many an electric model has gone up in flames in this way.

PCM/PPM
These terms stand for Pulse Pause Modulation (PPM) and Pulse Code Modulation (PCM). Common to both processes is that the RF signal is passed from transmitter to receiver using FM technology. A PPM LF signal consists of a chain of pulses containing mostly 8 channels (sometimes 9 channels - MPX). In its RF section the transmitter modulates the RF signal with this LF signal chain. In a PCM transmitter a code is used which enables the receiver to detect errors in the signal, i.e. interference. If interference is detected, the PCM receiver is able to move the servos to positions programmed by the pilot (Fail-Safe mode). Alternatively the servos stay in the last valid position detected (NORMAL mode). In short, the PCM receiver has "intelligence", in contrast to PPM receivers, which pass on all signals to the servos unchecked, whether they originate from the transmitter or from a source of interference. PCM systems do not necessarily prevent crashes, and the whole matter tends to be a "matter of taste"; in any case neither system prevents the interference.

PCM receivers only work with PCM transmitters, and only with the same make of transmitter. It is not possible to operate a JR/Graupner PCM transmitter with a Futaba PCM receiver, nor vice versa.

The range limit of a PCM receiver is clearly defined, as the servos either run to the Fail-Safe position or remain where they are (according to programming) when the signal is lost.

Range checking
To repeat the most important point: installation conditions vary widely from model to model, but even so, everything usually works well. However, if you wish to avoid problems it is important that you check each new receiver and each installation. You should also check a proven receiver when it is fitted in a new model.

Of course, all the problems don't occur all the time; usually everything works straightforwardly. Nevertheless, unforeseen circumstances arise again and again which can lead to difficulties, and if these problems only rear their heads when the model is already in the air, then it's simply too late. All models are valuable in the sense that it must be worthwhile to prevent them crashing through foreseeable problems, especially since all the problems we have already discussed can usually be eliminated, or at least isolated and assessed.

So: carry out all the checks **BEFORE** you fly your model.

We also recommend that you carry out a "little" range check before the first flight of each session. This may well be enough to draw your attention to some new problem, perhaps due to failure of the transmitter's output stage, a defunct battery, a cable not connected correctly, a receiver aerial which has been torn out accidentally. No pilot of a real aircraft would dream of taking off without carrying out a pre-flight check. In our case this simply means checking the working systems at a range of 5 - 7 metres, with the transmitter aerial removed. Note that this only works if there are no other transmitters switched on.

Test schedule
It is important that you adopt a systematic approach to checking your RC system, as this makes the test reliable, and will give you faith in its results. Here are our suggestions for your own "test schedule":

Create conditions for a true comparison
As a basic rule range checks should always be carried out under the same, or comparable, conditions, so that strictly comparable results are obtained. For this reason it is always best to carry out your check at the same location under the same conditions, and it is certainly important to ensure that no other transmitter is switched on at the same time.

Establishing comparison values
For optimum results, first check a reliable receiver from an existing model. The model should have completed numerous successful, problem-free flights. Remove the receiver from the model and operate it with a battery and two or three servos. Start by walking over the test course, and note down the range you achieve. This now represents your standard range for all subsequent checks. But take care: even at one particular location the environmental conditions will change from day to day; for example, if the ground gets a soaking from rain, the range you obtain will be quite different. For this reason you should carry out comparative tests on one and the same day, i.e. when a new receiver is to be tested, first test the proven receiver, and then the new receiver under the same conditions.

Defining the range limit
The range limit now has to be defined. There is always a point at which the servos start to jitter slightly. You could adopt this point as the limit, but you would need to define how great the "permissible" jitter is. Many receivers start to jitter slightly relatively early, but then continue to generate valid control signals much longer than other receivers which may start jittering slightly later, but then almost immediately shut down; facts like these make testing very difficult. In our view, if you are checking your system without recourse to measuring equipment it is better to define the range limit as the point at which the transmitter's control commands are no longer passed clearly to the servos. For this reason always operate one transmitter stick continuously when range-checking, so that you can assess this without difficulty.

Test procedure
If your transmitter features an automatic "servo test" program, activate the program and walk away from the transmitter holding the receiving system, as you can then check the servo movements easily.
If you adopt this procedure, set up the transmitter on a table, chair or platform at a height of at least 1 m. Switch on the receiving system and hold the servos and battery in your hand, leaving the receiver aerial trailing towards the ground. The transmitter's test program will now cause the servos to move in a defined pattern. Always walk in the same direction, and always set up the transmitter at the same position, pointing in the same direction. Don't stand with your body between receiver and transmitter aerial when determining maximum range.

If your transmitter does not include a servo test program, you should walk away from the servos carrying the transmitter. You need to be able to see the servo movements clearly at long range, so fit a long output arm with a large sticker on it.

Set up the receiver and servos on a platform at least 1.5m high, leaving the aerial trailing down in a defined way. A camera tripod with a wooden plate fixed on top works well.

Always walk off in the same direction. Always hold the transmitter in the same way, for this can also cause significant differences. Don't stand with your body between receiver and transmitter aerial.

Naturally, you can carry out a range check with the aerial fully extended if you prefer, but this really just represents extra work. It is quite sufficient to fit the transmitter aerial but keep it collapsed. Under good conditions you may then obtain a range of up to 200 m, although 60 - 70 metres is often adequate.

Whenever you are testing equipment, ensure that no metallic objects such as table tops or similar are located close to the transmitter, or the location of the receiving system.

New receiver / new model
First carry out a range check outside the model, i.e. before installing the equipment. This is done by connecting two or three servos and the battery to the receiver, and switching on the transmitter with the aerial collapsed. Of course, in the ideal case you will be able to compare the results with the data you recorded with your proven receiver. If this information is not available, a guideline is around 80 m. This applies to an open field with dry ground, transmitter at least 1 m off the ground, receiver 1.5 m off the ground, aerial hanging straight down. However, this is not enough in itself, as the conditions may change when you install the system in the model.

The new receiver, having passed its first test, should now be installed in the model, and the check repeated. Set up the model at least 1 m off the ground, as the range may be considerably lower when the model is at floor level; in any case, this is not comparable with the un-installed test, and comparability is important if you are aiming for reliable results. The receiver aerial should be tensioned to the fin, and the model's fuselage (and thus also the receiver aerial) should be set at 90º to the test course along which you intend to walk.

Under these conditions the measured range should be around the same as previously obtained, i.e. when tested outside the model. A 10% - 20% reduction is normal, provided that you measured at least 80 m without the model. Now turn the model through 90º (receiver aerial pointing straight along the test course), and check the range in this orientation. Even in this position the maximum range should not be significantly less than in the un-installed state. In the interests of completeness it is worthwhile checking again at the two other 90º directions. Finally - of course - we should check the side of the model which we normally see most often in the air, namely from underneath.

If you are checking a power model, and especially if an (electronic) ignition system is installed, all these checks should be repeated with the motor running. This should ensure that the influence of the ignition system is detected, and also shows up the effects of electrical "noise". With the motor running, effective range should be the same, or only slightly less.

Never launch the model if you are in any doubt, or if the system is behaving erratically in any way. "Murphy" states that what can happen, will, and this is law is invariable.

Fault-finding
If the test results are markedly worse than in the initial check (without a model), we have to start trying to locate the problem. Always work steadily and systematically, never changing two possible causes at once. If long cables are used, e.g. for ailerons, disconnect them from the receiver and repeat the test. If an improvement is evident, shorten the cables, fit separation filters etc., always carrying out only one corrective measure at a time.

Is the receiver aerial deployed inside the fuselage, parallel to linkage wires or servo leads? If so, re-route the receiver aerial outside, running to the fin, and repeat the test.

Receiver battery a long way from the receiver (extended leads)?? Try plugging the battery directly into the receiver for test purposes.

If you locate the cause of the problem but cannot eliminate it, e.g. the engine ignition system, then you have to attempt to reduce the severity of the problem by altering the aerial deployment, or by changing the position of the individual radio control system components and their cables. You should not fly the model until everything works properly at a sensible range (max. 10 - 20% less than in the un-installed state).

If you are not sure, repeat the test with the transmitter aerial fully extended. Ask a friend to hold the transmitter, hold the model 1m above the ground, and the effective range should be at least 500m to provide a reasonable margin of safety when flying the model.

The model's first few flights should also be used to check that everything works correctly, and establish the actual range in the air. Usually a first flight is very exciting (i.e. nerve-wracking), and all you can think about is getting the Centre of Gravity correct. Once that is settled, most pilots give far too little thought to the idea of systematically testing the radio control system in all possible attitudes, and of establishing the "safety margin".

Just how great is the range?
This should be established carefully, by flying the model slowly towards the limit of your normal radius of action. Don't just fly straight away from yourself; instead fly the model in ever increasing circles, constantly operating one control, e.g. aileron left - right, so that you can observe whether the receiver responds to every control command without delay. If you reach the limit of your normal flying range without problem, it's time to check the "visual limit" too - but not beyond it!! When you notice the first, slight problem, immediately turn the model to reduce the range - but don't fly it straight back; sideways-on to the pilot is much better, as it avoids the end-on receiver aerial situation. If a more serious problem occurs, see if you can cure it by changing the orientation (angle) of the transmitter aerial.

What happens if you fly in a direction which causes the receiver aerial to be "end-on"?
It is important to check this, otherwise you may be in for a nasty surprise later. At a safe altitude, fly the model into a position some distance from you, and take up a course at which the transmitter will "see" the receiver aerial virtually as a point. If the aerial is tensioned to the fin, simply fly the model towards yourself, straight and level, and at some time or other the model's position will be such that the receiver aerial is pointing straight at the transmitter. If the model carries out an uncontrolled movement at this moment, the result will always be that the model changes its position, which will inevitably improve the position of the receiver aerial, so the experiment is normally completely safe.

What happens when I fly low past myself?
Checking this tests whether the installation in the model has produced directional effects in the receiving system. Many cases of gliders "falling out of thermals" can be explained by this phenomenon, and have nothing to do with turbulent thermal air. It tends to be a particular problem when wing-mounted servos and long extension leads are used. Fly the model at a safe altitude and at some distance from you, and angle one wing tip straight at the transmitter for a long period; the model should hold this attitude without any difficulty.

What happens if I fly a long way away close to the ground??
This is an important check for the highly skilled aerobatic power model pilot, for what could be finer than to zoom along the strip at full speed, less than 1 m off the ground - although the not uncommon brief "down-elevator glitch" at such times is not so pleasant, whether it is "finger trouble" or due to interference. Joking aside, if there is any chance that you will have to perform an out-landing, you really should check this aspect of the system deliberately. In all cases it is always better to fly low passes slightly to one side of you, rather than directly away from you, as this will reduce any adverse directional effects. This is nice to know when an emergency out-landing is called for. At very low altitude you may experience "run-time differences", depending on the terrain (see below).

Competition aerobatic pilots must test their system in every conceivable flight attitude, for nothing is more frustrating than to fly a precise manoeuvre, only to see the model carry out an unwanted half-roll in the turn-around manoeuvre.

How long will my battery last?
This question should also be an integral part of testing out a new model. If you own a battery charger which is able to display the charged-in capacity, you can easily test the receiver battery by recharging the pack after a flight of average duration, then recharge, and check how much capacity was charged in. This will tell you how many flights you can expect to complete on a single battery charge.

If you have a charger with Delta-Peak charge termination but no display of charged-in capacity, you can at least take note of the charge time and calculate how much current was removed; from this you can work out how many flights you can safely complete.
As a responsible pilot, you really should not take part in a joint club flying session, with many transmitters simultaneously in use, before you have answered all these questions satisfactorily. Provided that no incurable problems have cropped up, you can assume that you have a sufficient safety margin to cope with the more challenging conditions of club flying without problems.

All this may sound like an awful lot of effort, but even if it takes two or three hours, what is that compared with the value of a complex model, let along the time it took to build it??

If a serious problem occurs it is tempting to replace the receiver with one of a different make, but this is not advisable. You may solve one problem, but could easily provoke another, and it is much more sensible to locate the original problem and solve it. Replacing the receiver may only shift the problem rather than solve it.

Safety margins

Generally speaking, the greater the range, the greater the "safety margin". What does this mean?

Let us assume that we normally fly no further than 500m to the left and 500m to the right, and that effective range in the air under perfect conditions is around 1.5km in every direction, so long as we fly alone. This means that we are operating with a safety margin of 1000m (or 200%). The "safety margin" is the distance between our normal, necessary radius of action, and the maximum effective range.

Now other modellers arrive and switch their transmitters on, and this reduces your system's effective range to, say, 1.25 km; the safety margin is still 750 m (140%). However, if an unforeseen problem arises, such as ignition system interference, the safety margin may be reduced further until you can no longer fly to the normal 500m limit without problems occurring (safety margin 0 or negative).

A regular problem with electric-powered models is that the motor stops briefly or, if the motor is already off, it starts up briefly. These are reliable indications that you are operating right at the safety margin, at least temporarily, or at the model's momentary orientation, i.e. the accumulation of all the environmental conditions and the inadequacies you have built into your model is so large that even at very close range the receiver is suffering interference when the transmitter and receiver aerial are disposed in a particular way. In this case the speed controller reacts much more quickly than, for example, a servo, which does not have time to move the control surface and show a visible effect, and for this reason it is easy to believe that the speed controller is the problem. Actually this is a clear indication that there are problems in the arrangement of the model's receiving system.

Everything may work fine for a long period when the safety margin is so narrow, but all it needs is one extra environmental problem, e.g. an unfamiliar flying site with different adjacent channels etc., and the problem rears its head and causes a crash, although it had really been lurking for a long time. These are what we might term the "open event crashes", which only occur at busy flying sessions ("... I don't understand it; I've never had problems with this model, but today it has to pick your big event to let me down.")

Slow-fly receivers also suffer chronically from "absence of safety margin".

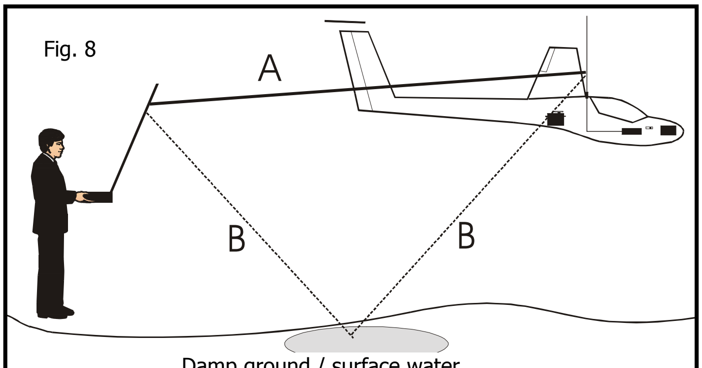
For this reason:

Always attempt to optimise the conditions for the receiving system as far as you possibly can, as this maintains as wide a safety margin as possible. You can then be sure that everything will continue to work perfectly even under difficult conditions.

"Black holes"

Oh yes, there are supposed to be such things in modelling. At some flying sites it is known that particular locations at a particular distance are hazardous, with repeated crashes reported. Whether everything might have been in good order on all the crashed models is a moot point, but the regularity of the crashes at a particular location is striking. What's going on?

Fig. 8



Damp ground / surface water

In our experience, based on measurements at a number of sites, the cause is usually wet ground, or even areas of standing water, which can reflect the signal and cause what are know as run time differences (see Fig. 8). The direct reception path "a" is shorter than the reflected reception path "b". Competently designed receivers can usually cope with this, but under certain conditions, e.g. when the safety margin (see above) is already reduced to nothing by other problems (i.e. the receiver already "has its hands full" just picking up the signal) then it is certainly possible for the receiver to fail under these circumstances at these locations. We have also been able to establish interference caused by large areas of cattle fencing, but there is generally more than just one culprit.

There also has to be a coincidental accumulation, i.e. the "problem" is a particular distance away, at a particular direction relative to the pilot, and also of a particular mass or length, in order to result in interference. To counter such problems you can try the following: optimise the system to produce a wider safety margin, change the transmitter position, and change the angle by raising the transmitter (pilots on platform).

Service

Now and then genuine problems do occur, and we have to resort to the manufacturer's service department; the same applies with crash-damaged equipment. The results are not always successful, and here are a few possible reasons for this:

Very few of our own receivers are returned to us (and this also applies to other makes). What we do find, however, is that as many as 99% of all returned receivers have no fault of any kind. Now, we aren't saying that customers send back their receivers just to annoy us; something must indeed have happened to cause the customer to return it. However, we can state with certainty that the tests described in this guide were not carried out in 99% of all cases, or at least were not carried out thoroughly enough.

Another problem is customers' fault descriptions, such as: ... when the receiver works, it works perfectly... or: ... on the last flight the system stopped working ... These comments are undoubtedly correct, but give us very little information to work on, and are therefore of very little help.

We have now adopted the practice of replacing returned receivers with new ones if we cannot determine a clear fault (99%), or if the customer does not provide a fault description which we can assess. In view of today's product prices, this is the only economic method of keeping our customers satisfied. We have never yet charged anyone for this.

However, we wish to point out clearly that any difficulty which the operator experienced will still be present if the cause of the original problem was not actually the receiver itself. This simply means that the responsibility for locating the correct cause **lies with the customer** - ALWAYS. So anyone who believes that a new receiver will cure all his problems, and therefore does not need to be tested, will continue to suffer interference if the original problem had nothing to do with the receiver.

The manufacturers would be spared a lot of wasted time and effort if customers were to test everything systematically beforehand, and then take care to localise the fault unambiguously. Indeed, this would certainly have a positive effect on our product prices - and probably on those of other manufacturers.

We wanted to write this guide in order to give you the information you require to eliminate problems in a systematic manner. Informed customers are important to us, as they invest their money well, and they know how to use our products competently. For us it is crucially important that levels of operational safety and reliability in ordinary club flying are as high as possible, as it helps to maintain the value of our customers' models. We do all we can to promote this when designing our products, but correct usage is also necessary. We are confident that this information will contribute to increased safety and reliability in the operation of all radio control products used in modelling.

We wish you many successful, trouble-free flights, and a generous "safety margin" at all times.

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