Radio Interference Problems for R/C Flyers

By Max Feil

Introduction

In the increasingly popular hobby of radio controlled model airplane flying, frequency congestion has prompted a series of changes over the years to allow more flyers to use the same frequency band. Today's dense frequency environment demands that extra precautions be taken to avoid interference problems, which in R/C flying can result not only in the loss of prized aircraft but personal injury or property damage as well.

I will attempt to explain in my own words the issues involved in trying to minimize both congestion and interference problems. I will start with some simple theory, and then apply this to the five main interference problems that can result with radio equipment that is in use today. The goal of this article is to stimulate discussion and increase understanding to allow the members of R/C clubs to update and improve their frequency rules to help provide a safe and enjoyable flying site.

Theory: Adjacent channels, IF, Intermodulation

First, some very general, oversimplified theory on radio interference causes. Keep in mind that I am not an RF engineer. I am also trying to keep things as simple as possible for the average R/C modeler. If anybody wants some more detailed, technical information, I have a very good article sent to me by somebody who works in the radio industry that I can pass on to you.

When we talk about the frequency that an R/C radio system operates on, we really mean its “center frequency”, since both the transmitter and receiver operate within a band of frequencies that is several kilohertz (kHz) wide. Your transmitter will transmit strongest at frequencies very close to its center frequency, with a decrease in signal strength as you move away from the center frequency. Similarly the receiver will be most sensitive to frequencies very close to its center frequency, with a decrease in sensitivity as you move away from the center frequency. Note that the center frequency of the receiver can be slightly different than the center frequency of the transmitter and things will still seem to work ok, but since power decreases as you move out from the center frequency, range will be reduced. Incidentally, this is why range checks are important. A bad range check may indicate that either the transmitter or receiver are out of tune and their center frequencies no longer line up. A crystal change can produce the same effect. The radio must be fine tuned afterwards to ensure that the transmitter and receiver are centered correctly, both with respect to each other and with respect to other radios.

The width of this band of frequencies around the center frequency is a major factor in determining the effects of radio interference. If your receiver encounters a second signal that is too close to its center frequency and the two bandwidths end up overlapping too much, then interference will result. The closer the interfering signal is to the receiver's center frequency, the less power is needed to cause interference. In the extreme case, if somebody turns on their transmitter and is on exactly the same frequency as you, you may crash even if their signal is very weak, for example if their antenna is down or if they are flying several kilometers away. Conversely, if somebody is operating on a frequency that is quite far away from the center frequency of your receiver, they can still interfere if their signal is strong enough. I will come back to this point later.

If this was the only way that interference could result, life would be simple. However there are several other RF interference mechanisms and they are much less obvious.

Pretty well all receivers convert the signals they receive to lower “intermediate” frequencies through the use of one or more special internally generated frequencies. The principle is called “heterodyning” and it involves mixing the received signal with locally generated frequencies in one or more stages. Receivers with one stage are called “single conversion” and almost always use an intermediate frequency (IF) of 455 kHz. Receivers with two stages are called “dual conversion” and usually use a first IF of 10.7 MHz and a second IF of 455 kHz. It is in the mixing process that several problems may be introduced which can result in unwanted signals showing up after conversion to the intermediate frequency. There are two main concepts here: “image frequency” and “distortion”.

Each conversion stage in a receiver will have an image frequency. It will convert not only the desired signal down to the intermediate frequency, but also any signal that is twice the IF either above or below the desired signal, depending on the type of conversion being used (high side or low side). For example, if you are using a single conversion receiver, the image frequency will be 910 kHz (45.5 channels) away, either up or down (but not both). If another transmitter in the R/C band is operating at this frequency, you may experience interference. Note that image frequencies are not a problem for dual conversion receivers since at each stage they are far away from the desired signal and therefore easily filtered out beforehand.

The signal mixers that are used to perform frequency conversion in the receiver also introduce a certain amount of distortion. This results in the creation of extra frequencies called “harmonics” and “intermodulation products”. Harmonics are simply signals at multiples of the desired or “fundamental” frequency. This is similar to what happens when you hit a piano key or pluck a guitar string. For example, if a radio frequency of 72.030 MHz is present, then distortion will create harmonics at 144.060 MHz (2 x fundamental), 216.090 MHz (3 x fundamental), etc. The power of each successive harmonic (2nd, 3rd, 4th, etc.) is generally lower than the previous one. Luckily, harmonics are so far away from desired signals that they are easy to filter out. Intermodulation, on the other hand, is perhaps the most important concept of this article. It takes place when more than one radio frequency is present, and is defined as the production of sum and difference frequencies from the set of original frequencies present. For example, if two frequencies f1 and f2 are present, they will “intermodulate” and produce two additional frequencies f2 minus f1 and f1 plus f2. These are called the 2nd order intermodulation products (2IM). To help illustrate this, I will point out an effect similar to intermodulation that is noticeable in everyday life. When two tuning forks of almost the same frequency are struck at the same time, a slow pulsating “beat frequency” is created which is quite audible. This is the difference frequency you are hearing. Anybody who plays guitar will also recognize that difference frequencies play a big part in being able to tune their instrument. Now let's go further and note that the 2nd order intermodulation (2IM) products combine further with the original frequencies to again create sum and difference frequencies that are the 3rd order intermodulation products (3IM). Luckily, with each successive order of intermodulation (2nd, 3rd, 4th, etc.) the power of the signal decreases. As an example, consider two people flying, one on channel 44 (72.670 MHz) the other on channel 40 (72.590 MHz). The sum and difference frequencies created are 145.260 MHz and 80 kHz respectively. These are the 2IM frequencies, of which 80 kHz is the more important one. The 80 kHz signal recombines with the two original frequencies to produce new signals with frequencies of 72.590 - 80 = 72.510 MHz and 72.670 + 80 = 72.750 MHz. These are 3IM products, and note that they correspond to channels 36 and 48! They are usually not a big problem since the power of third order products is quite low. Also, newer receivers are quite good at keeping intermodulation products generated within themselves to a minimum.

Note that not all intermodulation products are created inside the receiver. Some intermodulation products are actually created within transmitters that are operated too close together. Transmitters will generate significant levels of intermodulation if they are closer than about 20 feet together.

So, now we have talked about the sources of interference for a receiver, namely a signal being too close to either the main frequency or the image frequency, and we have also talked about how various (perhaps unexpected) frequencies are generated both by transmitters and within the receiver through intermodulation distortion.

Radio Systems: Old, 1988-1991, Post 1991

To lead up to a discussion of specific problems that need to be addressed at today's R/C flying field, I will start with a brief history of radios and radio frequencies in use in Canada and the U.S. I will concentrate on just the 72 MHz band, and ignore the 27 MHz (CB) band, the 50/53 MHz ham frequencies, and the 75 MHz surface frequencies.

In the past, the R/C spectrum was not as crowded as it is today. Most R/C activity was restricted to an original set of 6 frequencies which were specified not using channel numbers, but by using a two-colour flag system. Purple/white was 72.320 MHz, red/white was 72.240 MHz, etc. These channels were no closer than 80 kHz together, and the original radios were designed around this 80 kHz spacing and used single conversion receivers. In fact, in Canada many of these radios are still in use today, which is why many Canadian R/C clubs, including the Stetson Flyers and the Ottawa Remote Control Club, still follow 80 kHz spacing rules on their frequency boards through the use of a 5-pin wide system. The next step, which took effect in 1988, was the establishment of 50 R/C channels, all 20 kHz apart, starting at channel 11 (72.010 MHz) and running to channel 60 (72.990 MHz). Note that the 6 old frequencies fall “in-between” these channels, and therefore are sometimes referred to as “channel 26 and a half” or “channel 22 and a half”, etc. At first only even channel numbers were available, with odd channels slated for introduction in 1991. This meant a minimum possible spacing of 40 kHz.

Most flying fields still kept to the old 80 kHz spacing, especially in Canada where the original 6 frequencies were still in use. This meant that two people could fly only if they were at least 4 channels apart. This was the intent anyways, but due to non-linearities in the official MAAC (Model Aeronautics Association of Canada) frequency board, the 5-pin system actually restricted flyers to 120 kHz spacing between channels 32 and 46, and between channels 54 and 58. This was an unnecessary restriction and led to unneeded congestion which continues to this day.

In the several years between 1988 and 1991, radios were being sold that could handle a spacing of 40 kHz, and which were equipped mostly with single conversion receivers. Examples are the Futaba Conquest AM series, and the Futaba 5 channel PCM. Then, in preparation for 1991 and the introduction of the odd channels, these so-called “wide band” radios were phased out in favor of “narrow band” radios. The new 1991 radios being sold today need to handle 20 kHz spacing, and most have state-of-the-art dual conversion receivers. However even in the strict 1991 environment single conversion receivers are still being sold for some radios (for example the Futaba Attack AM series, and some JR receivers which have special circuitry called ABC&W - “Automatic Blocking Circuit with Window”).

So we have seen a progression of radio models, basically in three categories based on their capabilities:

1) Old: 80 kHz spacing, single conversion rx, wide band tx.
2) 1988-1991: 40 kHz spacing, single conversion rx, wide band tx.
3) Post-1991: 20 kHz spacing, single/dbl conversion rx, narrow band tx.

When we talk about a “narrow band” radio, we mean one that can handle 20 kHz spacing with multiple frequencies in use at the same time. Unfortunately not all 1991 radios come with true “narrow band” receivers, just narrow band (“gold stickered”) transmitters. The idea is that the manufacturer attempts to ensure that you never shoot somebody else down. However if your receiver is not narrow band (i.e. not dual conversion or ABC&W), somebody with wide band equipment can still shoot you down. This is rather like the world of automobile insurance, where liability insurance is mandatory but collision insurance is optional.

In Canada our situation is more complicated than in the U.S. We get 99% of our radio equipment from the U.S. and follow most U.S. rules, but unlike in the U.S. we have not taken any steps toward obsoleting old equipment. There are still a fair number of radios in operation from category 1 (above), and many radios in operation from category 2. In the U.S. some of these radios may still also be in operation, but since their use is much more discouraged there is less chance of encountering one, especially at a sanctioned flying site.

Problems in Today's Environment

Our goal is to make available as many R/C channels as possible while doing our best to ensure that no potential for interference exists. There will always be unanticipated factors such as radios out of tune and interference from external non-R/C signals, but we want to at least avoid known problems. We also want to explore all possible options before making rash, hard-to-enforce decisions such as banning certain types of radio equipment or disallowing certain channels.

The following five problems must be handled:

1) Spacing

We would like to use as narrow a spacing as possible, however two radios must not operate on frequencies closer than the spacing they are capable of handling. 20 kHz spacing (i.e one channel apart, for example one flier on channel 30 the other on 31) is only possible if both fliers have narrow band transmitters AND receivers. If one of the fliers has a wide band transmitter OR a wide band receiver, then the spacing must be wider, for example 40 kHz or 80 kHz.

2) Image frequency

Anybody using a single conversion receiver should ensure that no other transmitter is operating 910 kHz away. Luckily this affects only a few people since

910 kHz spans almost the whole 72 MHz band and since one transmitter would have to be on an old half frequency. The only radios likely to be affected (in order from most likely to least likely) are those on channels 14.5 (brown/white), 58.5 (yellow/white), 60, and 13.

3) 2IM

No two radios should operate on frequencies such that their difference is too close to the intermediate frequency of any single conversion receivers being used. For example, if somebody is on channel 42, and somebody else is on channel 19 the difference frequency is 460 kHz, which is very close to 455 kHz. This could affect EVERY single conversion receiver in the air. *They could all crash* no matter what channel they are on. Fortunately, not all single conversion receivers seem to be affected since 460 kHz is not right on 455 kHz, and since they have varying abilities to suppress unwanted distortion. Receivers from radios in categories 1 and 2 (above) will tend to be more affected. (I had one crash and one near crash due to 23 channel 2IM with my Futaba 5 channel PCM that I bought in 1988.) There is no easy way of telling which single conversion receivers are more susceptible than others. The only sure way to avoid this problem if we don't incorporate it into the frequency board is for *everybody* to use only dual conversion receivers, but this would obsolete at least 50% of the radios out there, at least in Canada. Note that the main reason a dual conversion receiver is not affected by 2IM is that all direct sum and difference frequencies that can be created in the 72 MHz band fall either way below or way above 10.7 MHz. Also note that this is a recent problem. *Before the introduction of the odd channels, this could not happen. Two even channels can never be an odd number of channels apart (23).*

4) 3IM

While not a big problem, 3IM is still an issue, as it has always been. The best protection for this problem is to ensure that people always stand in their pilot's box when flying so that no two transmitters with their antennas up come closer than 15-20 feet to each other. This is because those intermodulation products that are created within transmitters increase in power if the two sources are close together. Another rule to keep in mind is not to walk too close to somebody else if both your antennas are up.

5) Strong signal overpowers receiver.

This problem is quite common. If two flyers are standing relatively far apart, say at opposite ends of the flight line, and the first person flies their plane too close to the second person, the second person's radio signal will be so much stronger than the intended signal that the first person's receiver may experience a short burst of interference. This is in keeping with the discussion earlier which explained that an interfering signal need not be close in frequency if it is very strong. The best solution here is the same as in problem #4: stand in your pilot's box. Pilot boxes should be far enough back from the edge of the runway so that no plane will get too close in normal circumstances. Safe flying practices, i.e. low passes only over the far side of the runway, also help here.

Frequency board & club rules: Possible solutions

Well, I've said almost all I can. The next step is to design an improved frequency board and/or modify club rules. I will now very briefly list some of the solutions that I have heard other clubs put in effect:

i) Ban odd channels.
ii) Allow the use of dual conversion receivers only.
iii) Go to a special pin system that forces you to take all necessary pins, for example the pin(s) for channel(s) that are 23 channels away. An effective system is described in the AMA handbook (see me for more information).
iv) Go to a special computerized frequency board where the computer decides whether you can fly based on rules similar to those listed earlier.

In conclusion, there are some basic principles involved in radio interference, and these result in about 5 main problems that a frequency board and field layout must overcome. The first and third listed above, namely spacing and 2IM, are the most pressing, especially with the introduction of the new odd channels in 1991.

I have not dealt specifically with interference from non-RC sources, for example pagers (a problem in the U.S.), 2IM from audio of TV channel 4, etc. This type of interference will follow the same basic principles as I stated in the body of the article, but will be unique to a particular flying site and will require local rules.

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