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JUST HOW DOES SPREAD SPECTRUM RC REALLY WORK?

If you've got, or you've been thinking of buying, a 2.4GHz spread-spectrum RC set then you'll probably be keen to understand exactly how it works, and hopefully this article will help you do so.

First, a few words about older "narrowband" RC systems...

Traditional narrow-band RC systems on anywhere from 27MHz to 72MHz are fairly easy to understand because they work just like your regular AM or FM radio - sending out a signal that is picked up by the receiver and then sent to the servos.

Unfortunately, just like regular FM broadcast radio, these RC systems require a frequency all to themselves if they're going to avoid interference with each other. What's more, it doesn't take much to disrupt a regular narrow-band signal. A noisy thermostat or electric drill can often cause massive amounts of electrical interference when listening to an AM broadcast and FM isn't always that much better.

But manufacturers of spread spectrum (SS) radio systems are claiming that you need never worry about being shot down by other fliers and that all 2.4GHz systems can get along in harmony, despite apparently using the same frequencies.

So how can that work?

Well to explain this, I'm going to use a series of illustrations that I call "the freeway analogy". Using these diagrams and explanations, I will do my best to convey the complex world of spread spectrum in a form that most people can get their brains around. Of course in doing this I've had to take a few liberties with the details but these are not important.

Which Flavour of Spread Spectrum?

YES, IT COMES IN DIFFERENT FLAVORS

Before I launch headlong into a detailed explanation, it's worth pointing out that there is more than one flavour of spread-spectrum.

The first and most common type is what we call **Direct Sequence Spread Spectrum** (DSSS). This involves the transmitter and receiver staying within a fixed part of the 2.4GHz spectrum.

The second type is called **Frequency Hopping Spread Spectrum** (FHSS) and involves having the transmitter and receiver constantly changing their operating frequency within the alowed limits of the 2.4GHz band.

At the present time, only Futaba and Airtronics use FHSS, the remainder using DSSS.

And right now I can year you asking *"which flavor is best?"*... to which I have to say... neither and both.

Or, in other words, neither solution is best all the time, there are benefits and drawbacks to both, as you will see. However, it's safe to say that in theory, the Futaba FASST system does give the best of both worlds because it is not only FHSS but also DSSS.

But first, let's see how a traditional "narrowband" FM RC set works on frequencies such as 27, 35, 36, 40, 41 or 72MHz.

How do traditional RC systems work?

NARROWBAND FM/PCM RADIO CONTROL

Ever since the first radio control systems for models were built over half a century ago, the technology has been "narrowband".

Narrowband refers to the amount of space that signal takes on the spectrum of available frequencies.

Today's FM/PCM radio control systems operate on a tiny sliver of space on relatively low frequencies (27, 35, 36, 40, 41 or 72Mhz).

This tiny allocation of bandwidth for each RC channel creates a number can be likened to riding a bicycle down a narrow trail and the same problems apply:

Firstly, you can't ride very quickly simply because it's such a squeeze to get past the bushes and fences either side of your trail. In radio terms this means you can't send the control information between transmitter and receiver very quickly.

Secondly, if you run into another cyclist on that narrow track, chances are that you'll both fall off and get hurt. In radio terms it means that almost any other signal on the narrowband frequency you're using will result in interference (glitches or lock-out).

Clearly this isn't the best situation for controling a potentially expensive and sometimes dangerous radio controlled model but, with careful channel management, it has served us well for decades.

Distributed Spread Spectrum (DSS)

SPREAD SPECTRUM EXPLAINED

Distributed Spread Spectrum radio can be likened to a multi-lane freeway where your car seems to appear at random in different lanes. In fact, it appears and disappears so quickly that it almost appears to exist in all lanes at the same time.

In radio terms, the transmitter uses a wide spread of frequencies to send data to the receiver, rather than the very narrow band of frequencies used by the older narrowband RC sets we've seen up until now.

So what's the point in spreading yourself so thinly?

Well if you stop and think about it, if your "DSS" car encounters another on the freeway, it won't have very much effect. Your own vehicle won't be blocked because it will simply continue past when it suddenly appears in another lane which isn't blocked.

In radio terms, a single (or even quite a few) other transmissions won't have much effect on your RC system because they'll only block a tiny amount of the signal being sent. In fact, unless the freeway is almost completely blocked, at least some of the signal from your transmitter will get through to deliver your control inputs to the receiver.

Even better, if another DSS transmitter (or even several more) is operating on the same channel, it is also unlikely to interfere because it'll be jumping lanes in a different sequence and at a different rate.

So in a DSSS system, the last SS stands for Spread Spectrum and the first two letters stand for Direct Sequence. This relates to the order and frequency at which your vehicle moves between the lanes.

How DSSS Handles Interference

THE BATTLEFIELD ANALOGY

Another way to help you understand how a DSSS system avoids being "shot down" by interference is the battle-field analogy.

When an army goes into the modern battlefield, they're usually ordered to "spread out" -- and that's exactly what DSSS does, it spreads your transmitter's signal out over a much wider area than is the case with FM/PCM gear.

Just as on the battlefield, it's much harder to kill an enemy when they're spread over a wide front, so it is with a DSSS radio signal.

The chances of any single rifle-shot actually hitting a soldier on the battlefield is significantly reduced when they're widely spaced across the whole front. With DSSS, your radio signal is similarly spread very thinly across the radio spectrum and thus virtually immune to enemy fire, unless that fire is very intense.

By comparison, a closely grouped army of men can be decimated in moments by a single mortar shell or burst of machine-gun fire. That would be the equivalent of your old RC gear being shot down by interference or another transmitter on the same frequency being turned on while you're flying.

So what if someone turns on another DSSS system that uses the same channel you're already on?

Well because DSSS spreads your troops so thinly across the battlefield, there's plenty of room for another platoon from a totally different army to run between the ranks without the two colliding. This is why multiple DSSS systems can co-exist on the same channel without interfering.

Which radios use DSSS

Of the currently available 2.4GHz spread spectrum systems, all use some form of DSSS but others, such as the Spektrum/JR and Futaba FASST systems use other techniques to offer even greater protection from interference.

Several other systems that have gained a small following are those from XPS, Assan and iMax. These also use DSSS but appear to have no effective way of coping with the kind of crippling interference that might leave the other systems unaffected.

More of this later...

How do FHSS RC systems work?

FREQUENCY HOPPING SPREAD SPECTRUM

Frequency Hopping Spread Spectrum radio systems work by constantly hopping between a number of frequencies.

If you've just read the description of how DSSS systems work you're probably wondering "what's the difference?"

Well, whereas the DSSS system is like a car that repeatedly appears and disappears on various lanes of a freeway, at such a rate that it almost appears to be everywhere at once, a FHSS system effectively sees your car not simply jumping a small distance to a nearby lane, but all the way to a completely new freeway.

In radio terms, this means that the frequency sent by the transmitter doesn't just jump around within the chosen operating channel but actually jumps between a whole range of different channels.

It can be seen that, at least in theory, the FHSS system should be even more immune to the type of congestion that would cause problems with a DSSS system. That's because although nothing may get through while it was using a very congested freeway, the hop to a less congested one would allow the normal transfer of data to resume.

Under normal circumstances a FHSS system hops between a fixed number of channels in a repeating random sequence. When multiple FHSS systems are used together, the random anture of the hopping sequence means it's very unlikely you'll find multiple sets trying to use the same channel (freeway) at the same time.

How FHSSS Handles Interference

THE BATTLEFIELD ANALOGY

In a pure FHSS system, the troops are all closely grouped together as was the case with an old narrowband system but, because they're constantly jumping from battle-field to battle-field, the effect of enemy fire in any particular field is minimal.

Imagine that the whole army is teleported onto a battle-field and then, before you realise it, telported away to another. Clearly this makes a FHSS system a hard target for interference to hit.

However, the FHSS systems we're seeing used in radio control systems right now are a blend of both DSSS and FHSS. This means that not only is the signal spread across a whole channel but it also hops continuously from one channel to another.

This means that an FHSS system is an incredibly difficult target for any interference to hit -- and when you're flying RC models, that's a very good thing.

Which radios use FHSS

Right now, only two readily available 2.4GHz spread spectrum radio control systems use FHSS. These are the FASST radios from Futaba and the Airtronics offerings.

Belt and braces

EVEN MORE PROTECTION AGAINST INTERFERENCE

By now you've probably realised that spread spectrum technology offers some very clever ways to reduce the effects of interference and allow many different radio sets to operate simultaneously without the need for a frequency peg.

Thanks to the way these systems spread their signals thinly across the 2.4GHz band and thanks to the way some of them hop around so as to remain a moving target, it takes a very strong interfering signal to have any effect.

I've already explained that, at least in theory, the Futaba FASST system is probably the most bullet-proof SS system on the market, but the JR/Spectrum offering has also made it self doubly resistant to interference -- not by hopping all over the place but by adding a redundant channel.

As previously outlined, a DSSS system *can* be knocked out if the strength of an interfering signal on that channel is strong enough -- so JR/Spektrum reduces the risks by using two channels at once.

This means that even if a very strong interfering signal appears on a channel being used by your JR/Spektrum set, you won't lose control, and that's because the second channel on its different frequency will almost certainly be unaffected.

Reputable mnufacturers realize that their systems may be in control of very large, expensive and potentially dangerous models so they try to allow for as many contingencies as possible. Futaba uses constant frequency hopping, JR/Spektrum uses a backup channel (a tactic known as redundancy).

What is diversity?

Another important aspect of 2.4GHz spread spectrum radio control systems is something called diversity.

Diversity is required because the radio signals at 2.4GHz behave quite differently to those we're used to on lower frequencies such as 72MHz.

Whereas the old narrowband frequencies will pass right through most objects such as houses, trees, fences, and model airplanes, 2.4GHz behaves much more like light, being either absorbed or reflected by many parts of the environment.

This absorbing and reflecting of the 2.4GHz signal results in occasions when the receiver antenna by be shielded by some part of the model, or may even be subject to the kind of ghosting that used to be seen on old TV sets when the signal was reflected by trees or buildings (called multi-pathing).

The effects of shielding and/or multipathing mean that it's quite possible the receiver will be unable to hear the transmitter clearly enough to extract the data being sent.

The simplest (and best) solution to this problem is to use more than one antenna and/or more than one receiver in your model. By mounting these antennas or receivers in different places (even just an inch or two appart), one can take over if the other is unable to get a clear signal.

The JR/Spectrum system allows for multiple receivers, up to four or more and some of these receivers have mutliple antennas. This is surely the ultimate diversity setup. On very large models, you can be absolutely sure that there's no chance of shielding or multi-pathing by simply increasing the number and distribution of receivers within the plane.

The Futaba FASST system uses two antennas mounted on the one receiver. In theory this isn't as good as the JR/Spektrum option but in practice it seems to work perfectly adequately.

Summary by brand

COMPARING 2.4GHz SPREAD SPECTRUM RC SETS

I'm sure the big question most people want to know is "which SS system is best?"

Well the truth is that the big-name sets (**JR/Spektrum** and **Futaba**) are both pretty decent offerings that have a growing record of reliability and performance.

Of course if you ask enough people you're bound to find someone who has had problems with almost any brand of radio, and these new 2.4GHz systems are no better.

It's well worth remembering that we're still dealing with first-generation equipment here so there will inevitably be teething troubles and issues that need to be addressed. Indeed, both **JR/Spektrum** and **Futaba** have already faced some of these problems but things now appear to be quite stable.

I don't think anyone will be disappointed by purchasing either of these big-name brands so the selection criteria will most likely be based on your budget and the type of models you fly.

However, there are alternatives to the "big two" brands, although they remain less proven.

The **XPS** module-based 2.4GHz system is a single-channel non-hopping DSSS system that offers neither antenna nor receiver diversity.

Although many people have reported excellent results with this system, it is worth perusing the various discussion forums around the Web to read about the issues others have had with **XPS**.

Perhaps one of the biggest problems is not so much the technology as the man behind the product and his approach to marketing. Right from the start, the **XPS** system has been grossly over-hyped and under-delivered.

There are a growing number of former fans of the system who now freely air their disappointment, usually after losing models to unexplained lockouts or other failures.

Another second tier offering is the module-based **Assan** 2.4GHz system out of China, which is another DSSS non-hopping system. However, **Assan** do offer receivers with antenna diversity and there have been few reports of problems to date.

Another new entrant to the scene is the **iMax 9X** 2.4GHz RC system out of China.

Unlike **XPS** or **Assan**, the **iMax** system is a complete radio, albeit the transmitter can be used on 35/72MHz or 2.4GHz simply by swapping modules. It is far too soon to establish the robustness, reliability and ultimate perforance of the **iMax** system yet as it has only just started selling. (but look for a review soon on RCModelReviews.com).

So which is best?

As I said before, there's no absolute "best" 2.4GHz system because everyone's priorities are different.

If you want a system that offers a wide-range of different receiver sizes and capabilities with maximum diversity on very large models then the JR/Spektrum offering has much to offer.

However, if you're looking for a "technically superior" system, it's hard to go past Futaba's FASST. Unfortunately, at this time there are not a lot of receiver options and Futaba has been very slow on delivery of some options.

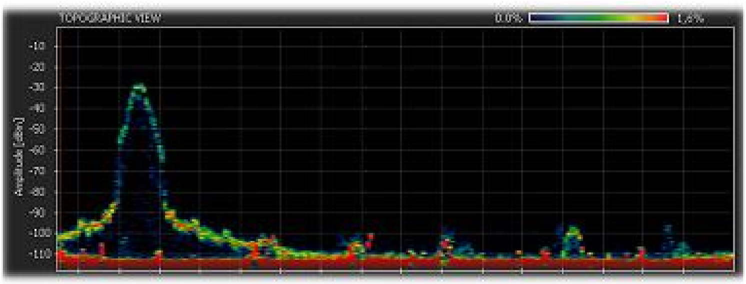
If you're prepared to be an early-adopter then the new wave of low-cost offerings out of China may be worth a try. Check their specifications carefully though, and also keep an eye on the various discussion forums around the web. As first generation products they may have some as-yet undiscovered problems or limitations.

About the only system presently on the market that I would be hesitant to recommend is XPS.

As I said earlier, many people have had no problems with this system and it has worked perfectly for them. However, from a technical perspective, too many of the system's wild claims are unable to be substantiated by the manufacturer and the growing number of dissatisfied customers must be a concern worthy of consideration.

The 2.4GHz Spread Spectrum FAQ

QUESTIONS AND ANSWERS TO THE 2.4GHZ PUZZLE



Do you have a question about Spread Spectrum 2.4GHz radio systems?

If your question isn't already here, use the feedback page to drop me a line and I'll do my best to come up with an answer

Q. Is it true that you can't be shot down on 2.4GHz?

A. It is true that you can't be shot down by another 2.4GHz radio control system but there is still always a chance that other forms of interference can cause you to lose control of your model. The 2.4GHz band is used by a very wide range of other electronic equipment from wireless internet to microwave ovens. There's no guarantee that one of these other devices won't interfere with your RC set.

Q. Are there disadvantages to a module-based 2.4GHz system?

A. There are some disadvantages to using a module based system over a totally 2.4Ghz one. The newer non-module-based 2.4GHz systems often offer higher resolution and faster response. The JR native 2.4GHz systems also offer a unique feature (Model Match) that elminates the risk of flying with the wrong model memory selected in your transmitter.

Q. Can I use my existing servos with a new 2.4GHz system?

A. Yes, all of the currently available 2.4GHz systems are compatible with conventional (analog or digital) servos. There is talk of a new generation of totally digital servos becoming available specifically for advanced SS RC gear but nothing has yet been seen. The only exception to this is that some Hitec digital servos may not work reliably (or at all) with some Futaba FASST receivers due a lower than expected voltage on the signal line.

Q. What causes lockouts on 2.4GHz?

A. Spread spectrum radio sets work in a way very similar to PCM ones in the way they respond to strong interference. If you're unlucky enough to experience interference so strong that the link between transmitter and reciever is lost, your receiver will enter "hold/lockout" mode and then go to failsafe mode (if set).

The cause of such a lockout/failsafe can be almost anything including, but not just limited to, interference. In fact, in the case of spread spectrum systems, experience has shown that lockouts are far more likely to be caused by inadequate batteries in the model or bad installation.

Q. Should I switch to 2.4GHz now or wait?

A. this depends very much on your own situation. If you've never had a glitch with your existing narrowband RC system and have no problems with frequency control at your flying field then there's no reason why you should rush out and by a 2.4GHz spread spectrum set. However, if you do live in an area where interference on your existing set is not uncommon, or if there are long queues for frequency pegs then the move might be worthwhile.

If you're just starting out in the hobby and don't yet have any RC gear then it probably makes sense to go straight to 2.4GHz.

Q. Why are good receiver batteries so important on 2.4GHz? A. Inside every spread spectrum receiver are an array of tiny computer chips that must perform millions of complex instructions without mistakes every second. In order to function reliably, these computer chips require a steady stream of electricity. If that steady stream is interrupted, even for a tiny fraction of a second, the computers can crash or stop working briefly.

This means that if your receiver batteries, BEC or regulator aren't up to scratch then you will almost certainly have real problems with your new 2.4GHz radio.

Unless you're flying helicopters with servos that can't handle the extra voltage, it is strongly recommended that you use a 5-cell receiver pack (6V) or even one of the new 2-cell A123 battery packs (6.4V) to further reduce the risk of voltage-related receiver problems.

Many of today's hi-torque servos can draw very high amounts of current and if your battery isn't up to the task, this can cause the voltage they deliver to be drastically reduced. Should that voltage drop below the 4.5V some receivers require to function, a lockout or reboot may result. Remember that when the computer in your 2.4GHz recevier crashes, its' quite likely your plane will also crash. Good batteries of adequate capacity and well-charged are absolutely essential to safe flight.

Q. Can I use a 2.4Ghz system in my carbon fiber glider

A. Unfortuately carbon fiber acts as a pretty good shield against 2.4GHz radio transmissions. This means that if you mount a 2.4GHz receiver inside a carbon-fiber fuselage, it probably won't work very well at all. For this reason, many glider fliers (especially DLG fliers) are sticking with narrowband radios where not only are the frequencies less affected by carbon fiber but at least some of the antenna can be routed outside the fuselage.

Some 2.4GHz receivers such as those from Futaba have extended antennas that make it easier to route them through the CF to the outside world. It's still very important to make sure that at least one antenna is visible from every angle.