


This presentation covers the hardware aspects of contest station design. It does not address antenna systems and the engineering thereof. Advanced topics such as SO2R station design are likewise not addressed.



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WHAT'S IT ALL ABOUT?

MAKING QSOs!

- Station Design goal is to maximize potential for making QSOs
- As with any competitive endeavor, superior results are achieved by attention to detail

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A contest station is designed to make the most QSOs possible. Careful design and attention to detail will always produce optimal results.



WHAT HELPS MAKE QSOs?

- Operator skill (of course!)
- Good Transmitted signal (i.e., be LOUD)
- Ability to hear signals in adverse environment
- Operator efficiency
- High station reliability and maintainability

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Although operator skill is far and away the single most important factor in producing good contest results, the quality of the hardware the operator uses can have a significant influence as well.

Obviously, a loud signal will attract more attention than a weak signal and therefore produce more QSOs. But just being an “alligator” won’t get the job done. You must be able to hear all callers and get their exchange information even in the presence of overwhelming QRM and noise. This is especially true on the low bands.

A station that is easy to operate will promote higher operator efficiency and hence higher rates. Good station ergonomics can promote high operator efficiency for longer periods and produce higher QSO totals.

The station hardware must work at its full capability without failure for the duration of the entire contest. In the rare case of equipment failure, the station must be designed to permit quick troubleshooting and repair to return it to service as soon as possible.

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HAVE A GOOD TRANSMITTED SIGNAL

MAKE THE MOST OF YOUR RF

- Antennas: Do the best you can with what you have
- Use only quality feedline
- Minimize losses
 - Build feedlines correctly
 - Use antenna tuners carefully
- Have a CLEAN signal

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Use the best antennas you can manage to install and maintain, but plan carefully to maximize the performance of what you can manage. Using cheap feedline and other RF components is a false economy that will degrade both performance and reliability of your station. With tuners, remember that just because the VSWR meter looks good it doesn't mean all the RF is getting to the antenna! Especially on the higher bands, lots of little losses can add up to a noticeable signal deficit.

Be sure the transmitted signal is clean. Clicky CW or splattering SSB is poor form and will discourage potential callers as well as disturbing other contest participants on nearby frequencies. Viewed on a band scope your signal needs to be high, not wide.

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HEAR THEM ALL

THE NAME OF THE GAME IS SIGNAL TO NOISE

- Match receiver dynamic range to your mode
- Use QRM fighting features of your receiver
- Have separate receiver antenna input available
- Consider using dedicated receive antennas for the low bands if possible
- Ensure good quality receive audio and AGC action
- Minimize Local RFI


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Take full advantage of the receiver performance you have available. CW is much more demanding of receiver dynamic range; SSB is mostly limited by the spurious signals from other transmitters. Learn how to use all the tools your receiver provides to pull signals out of the noise and QRM.

Having a separate receiver input available is invaluable for inserting various filters, antenna switching arrangements, etc. in the receive path. An arrangement that loops the receive antenna out from the T/R switch and back in is the best. Even a simple extra receiver input is very useful, but this won't let you process the signal from the transmit antenna in receive mode. Even many high tier transceivers don't provide a loop-through, but most can be modified to provide one. A separate receiver input also allows use of dedicated receive antennas, a very important thing for low band operation.

Bad audio will make it harder to pull callers out of noise and QRM and quickly cause operator fatigue. If your receiver audio amplifier is cursed with high levels of noise and distortion (as many are) try to select headphones with limited frequency response to suppress some of the offensive higher frequency noise content. For CW, an AGC characteristic that allows some differences in audio levels for signals of different strengths makes it much easier to separate multiple signals in the receiver passband.

Locate and suppress all local RF noise sources under your control. This includes not only unintentional emitters such as switching power supplies but also common mode RF interference from your transmitter.



USE YOUR RADIO'S QRM FIGHTING FEATURES

- Filter and IF bandwidth selection
- Passband Shift / Hi-Lo Cut
- CW Reverse
- Noise Blankers (be careful!)
- DSP noise reduction
- Audio filtering

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Even the most basic of modern radios have features that when used effectively can help pull a desired signal out of a crowded RF environment. The most basic is the range of IF selectivity choices available. Recent designs that use DSP techniques offer a wide range of filter bandwidths. Older designs that use cascaded crystal filters in multiple IFs also provide excellent performance.

The ability to shift the passband response to move an interfering signal outside the filter is an extremely useful feature that is available on many transceivers. Its counterpart, Hi-Lo Cut, is especially useful for SSB.

Many radios offer a CW Reverse feature that switches the CW offset to the other side of zero beat. This is a powerful tool to move QRM out of the filter response.

Noise blankers are not a panacea. When properly adjusted and used against impulse type noise they can be of significant value. Using heavy noise blanking against high duty cycle impulse noise or in a dense strong signal environment (i.e., a contest) can create artifacts that are more troublesome than the noise itself.

DSP noise reduction can be useful in some cases, but not usually in contest situations. If you have this feature play with it to see if you find it useful. This is a highly personal preference.

Some transceivers have additional audio filtering features that can be useful.

MINIMIZE LOCAL RFI

- Track down and kill external RFI sources
 - Switching Power Supply trash
 - Ethernet Birdies
 - Plasma TVs
- Use external noise cancellers
- Trap or filter BC station QRM
- Use directional receive antenna(s)

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Use linear power supplies if at all possible for the primary equipment power. You're stuck with all the garbage from household emitters, but there's no need to ask for trouble in the shack.

Killing radiation from switching power supplies and computer network cables will demand that you lay in a stock of ferrite cores and apply them to every offending cable you can locate. Plasma TVs will probably only respond to instant lead poisoning, but directive receive antennas or cancellation devices like the MFJ-1026 or Timewave ANC-4 can be effective against a single source problem.

Nearby MF Broadcast transmitters can be troublesome on the lower bands. There are a number of commercially available high pass or band reject filters that will solve the problem.

Directional receive antennas such as loops, beverages, K9AY arrays, etc. can do a good job of discriminating against noise or QRM from discrete sources.

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MINIMIZE LOCAL RFI

- Transmitter generated RFI
 - Common Mode chokes
 - Proper bonding & RF return paths
 - Quality feedlines
 - Antenna type selection
 - Antenna physical separation
- Coax switches with poor isolation
- Poorly shielded receiver cables

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Common mode RF is a significant problem in installations where the antenna is close to the station, i.e., most “normal” home stations in an urban or suburban environment. Manage CM noise with chokes and by bonding the chassis of equipment together with low impedance conductors. Make CM currents flow harmlessly on the outside of equipment enclosures along the bonding connections rather than letting it get inside the vulnerable electronics via signal cable shields and conductors.

Poor quality coax cable with ineffective shielding will cause problems two ways: On transmit, it will cause RF to radiate where it shouldn't. On receive, poor shielding will allow electrical noise and interfering signals to enter the receiver from unknown directions.

If possible, avoid antennas with known common mode RF problems such as off-center fed dipoles or verticals that couple into adjacent conductors.

Coax switches and antenna relays with poor isolation can couple unwanted signals into the receiver and degrade the pattern of directional antennas.

STATION ERGONOMICS

LESS TIRING = MORE EFFICIENT = BETTER RATES

- Good Display Management
- Efficient Control Location
- Maximize Automation
- Good Operator Ergonomics

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If you're not comfortable at the operating position you'll tire and lose efficiency quicker. Tired operators can't keep up the rate as well.



DISPLAY MANAGEMENT

- All important information in immediate field of view
- Primary computer display centered at eye level
- Maximize screen real estate
- Ancillary displays within field of view if possible

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Having the things you need to see to operate in your immediate field of view is very important. Nothing will induce aches and pains faster than needing to continuously swivel or bob your head to see important information. This is an increasingly bigger problem as the age of the average contestee advances and the field of view through the inevitable eyeglasses narrows.

EFFICIENT CONTROL LOCATION

- Place radio so that main tuning knob falls easily to dominant hand (but not behind keyboard)
- Group related functional controls together
- Place frequently used controls closer to operator
- Locate lesser used controls at periphery of operating space

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Locate as many frequently used controls as possible so they fall readily to hand. Locating important controls in awkward positions is a good way to induce fatigue. You should not have to reach in different directions to perform closely related tasks. For example, don't put the antenna selection controls on the left and the rotator control on the right. Things like antenna tuners and amplifiers that are adjusted less frequently in normal operation should be farther away from the operator than controls that are used all the time.

EXAMPLE STATION LAYOUT



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My station as of September 2012. I think I have it set up pretty well. It looks like a lot of complication, but since I'm an old timer who has done lots of paper contest logging and CW traffic handling I'm used to using my left hand to turn all the knobs. All the controls that select or turn antennas are clustered in the same area. The SO2R controller is near the primary radio tuning knob. The keypads for the microHAM Station Masters turn out to be incredibly useful.

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MAXIMIZE AUTOMATION

COMPLEXITY = CONFUSION = ERRORS

- Computer control of radio via *familiar* logging software
- Automate antenna selection
- No-tune amplifier if possible
- If you MUST use an antenna tuner, consider an autotuner
- Computer control of antenna rotator
- Relays are your friend...

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Total automation is the goal for efficient high rate operation. Ideally, changing bands on the radio or via software control should automatically select the appropriate antenna and switch all other functions required. Be sure you're familiar enough with your contesting software that it doesn't slow you down.

Having to execute complicated manual switch changes to change bands, especially when you're tired, is a great way to screw up. When an amplifier is involved it's a REALLY great way to screw up.

Requiring antenna tuner adjustments to change bands really slows down QSY. Try not to need tuners for your antennas. If you absolutely need an antenna tuner, one of the many available automatic tuners is best, particularly if it can be mounted near the antenna feed to minimize losses.

Some homebrew hardware using relays can often make antenna and custom control switching chores much simpler. Relays are cheap, reliable and have ZERO RFI or software problems.

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GOOD OPERATOR ERGONOMICS

- Keyboard home row centered on computer display
- Proper desk & chair height for keyboard
- Quality ergo seating
- Subdued lighting for night operation
- Minimize connections to radio front panel
- Good receiver audio quality
- Use multiple headphones & change occasionally


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The ergonomics of modern contesting are fundamentally no different from any other computer intensive activity. The big difference is that there are more things to do and you're likely to put in much longer operating stints at the contest station than at a work activity. Therefore, good ergonomics are even more important.

Clutter on the desktop should be avoided. Cables plugged into the radio front panel that intrude into operating desk space can interfere with normal keyboarding and radio tuning.

Good receiver audio is important to maintain operator efficiency. Always use headphones — speakers won't let you concentrate on digging signals out of noise and QRM. Keep the audio levels as low as possible to minimize listening fatigue.

Have more than one set of comfortable headphones available and switch between them occasionally. Cheap uncomfortable headphones are a false economy. If your radio has lots of annoying high frequency hiss in the audio, select headphones with restricted bandwidth rather than using hi-fi types.




HIGH EQUIPMENT RELIABILITY & MAINTAINABILITY

- Careful Station design
- Use only high quality interconnects
- Maintain good documentation

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Careful design using high quality hardware will help ensure the station works well in the stress of contest conditions. Nevertheless, failures WILL occur. Good documentation is essential to find and fix failures quickly.



CAREFUL STATION DESIGN

- Plan equipment layout and RF & Control cable routing carefully
- Design for maximum flexibility
- Plan for future complexity growth
- Plan for backup hardware

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Based on ergonomic considerations, plan the equipment layout and how you intend to route the RF and Control cables between the various components. We all know “wireless” is one of the biggest lies in the English language when it comes to putting together a radio station. Some planning of the cabling prior to construction will help to keep down the tangle factor. Cable trays or other wire management aids are very useful. One pound black boxes with ten pounds of cables attached to them demand external support for the weight of the cables (don’t ask me how I know this).

Assess the capabilities of your available equipment and engineer the station to take advantage of all its features. For example, if your radio has an external receiver antenna input available, try to come up with a way to switch any and all antennas not being used for transmit to the receiver input. You’ll probably have to build some custom hardware to do this, but it’s well worth the trouble.

As your station evolves, it will almost certainly grow in complexity as you add additional capabilities. Try to anticipate this growth and don’t do anything that will make it hard to add hardware in the future. This especially pertains to design of the operating table. If you have the space, bigger is always better.

Failures are inevitable. Thanks to Mr. Murphy these will usually happen in the middle of the contest. If you have backup equipment available, plan in advance so it can be moved into place in the station if the primary equipment fails. In the case of radios, have a set of adapter cables for critical control interconnections that will let you plug in the existing cables to get up and running with the backup.

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USE QUALITY INTERCONNECTS

- Homebrew audio & control interconnects from *stranded* CAT5 cable
- Use brand name connectors from reliable sources
- Use quality coax
- Build UHF connectors properly using appropriate tools

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Cheap shoddily built cables are an all too common cause for all kinds of troubles. The more complex the station hardware, the more important it is to use high quality interconnecting cables.


Excellent audio and control cables can be built from cheap and readily available CAT5 network cable. Be sure to use the stranded wire variety. CAT5 cable has the advantage of twisted pair construction, which is much more effective at rejecting RFI than shielded construction.

Cheap connectors are another false economy. Mouser Electronics and other suppliers carry high quality connectors at reasonable prices. For audio, I use Rean connectors. For DIN plugs and RF connectors, Amphenol is the best choice. Hamfest RF connectors don't always meet full electrical and mechanical specs.

Cheap coax is cheap for a reason. Quality cable has better shielding and is made from better materials. LMR-400 and its variants is good for high power and quality RG-8X with a heavy copper shield is good for low power interconnects. Cable Warehouse sells good quality RG-58 BNC cables for receiver interconnections.

Properly constructed RF cables using high quality UHF (PL-259) connectors will last forever. Many purported shortcuts for assembling UHF cables exist, and all have problems that will ultimately give troubles at the least opportune time. Check the Amphenol web site or any ARRL Handbook for instructions on how to build UHF cables and follow them to the letter. The secret to building UHF cables is to use a BIG

soldering iron (not a gun) and to prepare the cable properly. DX Engineering sells a very useful stripper tool for both small and large coax. Some advocate crimp connectors, but crimping tools that do the job properly are extremely expensive items. The usual \$40 hamfest crimper won't get the job done.



MAINTAIN GOOD DOCUMENTATION

- Label ALL cables at each end
- Draw or list all interconnections
- Draw schematics of homebrew hardware

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When, not if, something goes wrong it's important to know how the station is wired. Lying on your back under the radio table and trying to trace an unlabeled RCA cable that's been pulled out of a socket someplace in the rat's nest is a good way to lose valuable operating time and mental acuity in the heat of a contest. Take the time to carefully document how all the cables and wires in your station are connected so that you will have a way to quickly find and fix connectivity problems that appear.

ALL interconnect cables should be labeled at both ends to make it obvious where they go. The name on the label should match the name of the associated equipment connector. I use zip ties with flags to make my labels. The label text is made using a Brother tape label machine. Don't be tempted to just write on the flag with a Sharpie. It will eventually fade and become unreadable. The following slide shows an example of this technique.

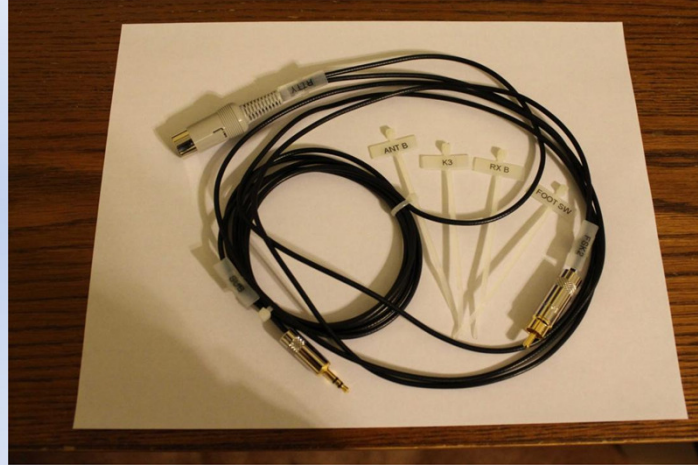
Labeling cables is one part of keeping track of how things are connected. The other is putting together a good block diagram that shows the interconnects and signal flows. For complex stations like mine, separate drawings for functional areas such as audio, Receive RF, Transmit RF, Computer interconnect, etc. let you put lots of information on each drawing without overwhelming detail. A good block diagram that clearly shows signal flow is also invaluable as a troubleshooting aid. Following slide #2 shows an example of interconnect diagram.

For multi-wire control cable connections, a detailed drawing or spreadsheet tabular presentation showing wire colors, pin and terminal numbers, etc. is very useful for

both initial construction and troubleshooting. Following slide #3 shows an example of a graphical approach.

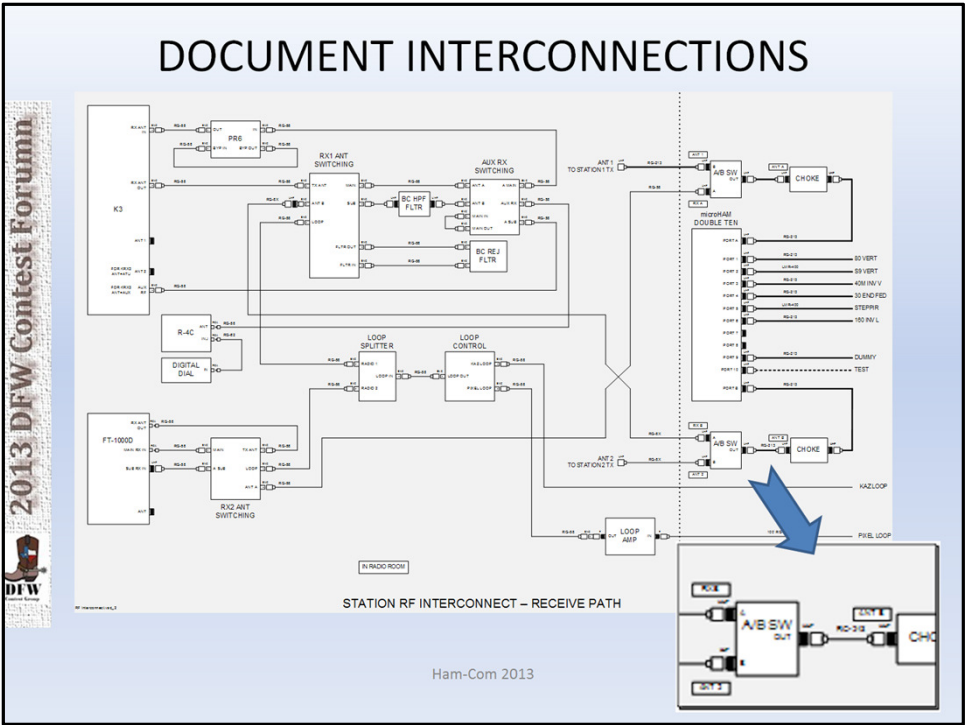
If you build custom hardware, be sure to document it properly with schematics and other information required. Otherwise you won't remember how it's supposed to work when it starts acting up.

LABELING CABLES

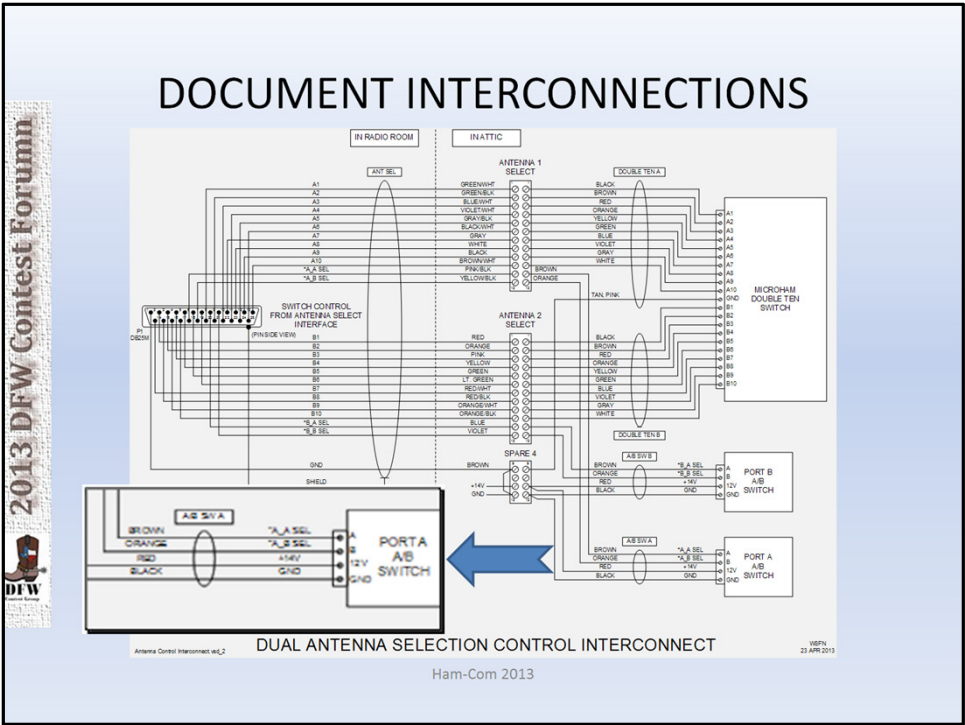


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Example of cable labeling using flag zip ties.



Example of detailed block diagram to show connectivity and signal flow



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Example of control wiring diagram

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CONTINUOUS SHAKEDOWN AND IMPROVEMENT

- USE the station outside of major contests
 - Work the DX pileups
 - Work minor contests & QSO parties
- Fix problems as they surface, not just before the next big contest!
- Make improvements well before major contests

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Regular use of the station outside of major contests will keep both the station and the operator tuned up and ready for competition. With regular use, the inevitable hardware and/or software problems will hopefully surface at a more convenient time than at the beginning of a serious contest effort.

Don't fix the broken microphone cable shield by immobilizing it with duct tape and rationalizing that you'll get to it later. Things always come up and before you know it it's contest weekend and the duct tape has come loose. Problems that develop should be corrected immediately upon discovery or as soon as possible thereafter. Don't wait until the last few hours before a big contest to do those little repair chores that will "only take a few minutes". They won't.

If you make major changes or additions to the station hardware do it well in advance of important contests to allow problems to be found and corrected. This can also help show whether a supposed "improvement" really makes things better or just different.

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CONTEST STATION ENGINEERING PRINCIPLES

- Minimize Transmit RF path losses and transmit a clean signal
- Optimize Receiver performance & flexibility
- Minimize local RFI
- Make the station ergonomically efficient with as much automation as possible
- Maximize hardware reliability and maintainability

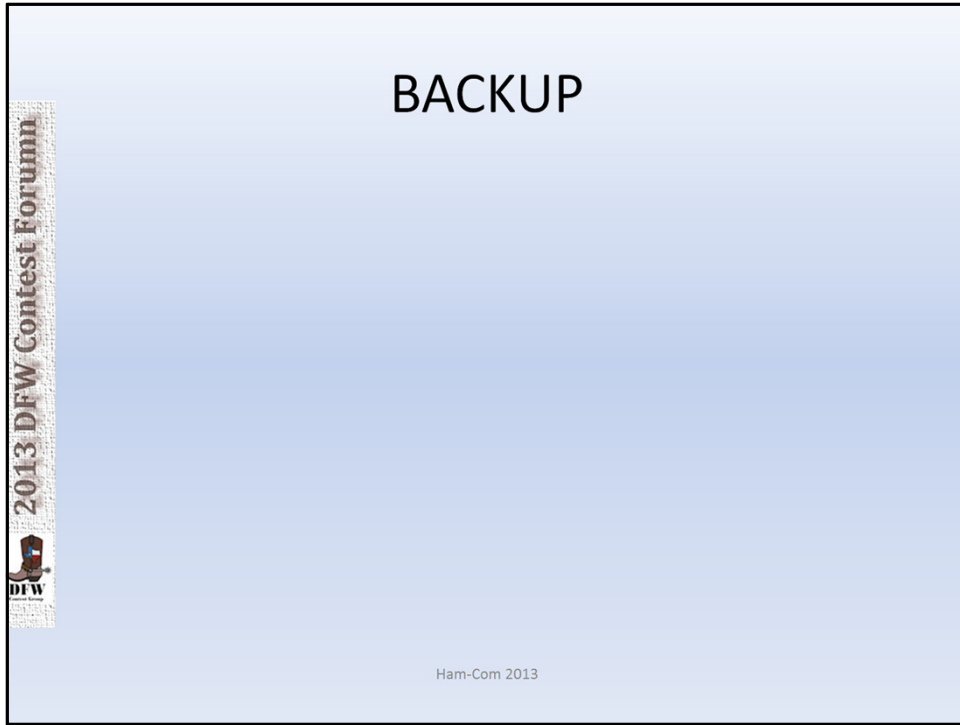
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These are the key principles to build a successful contest station

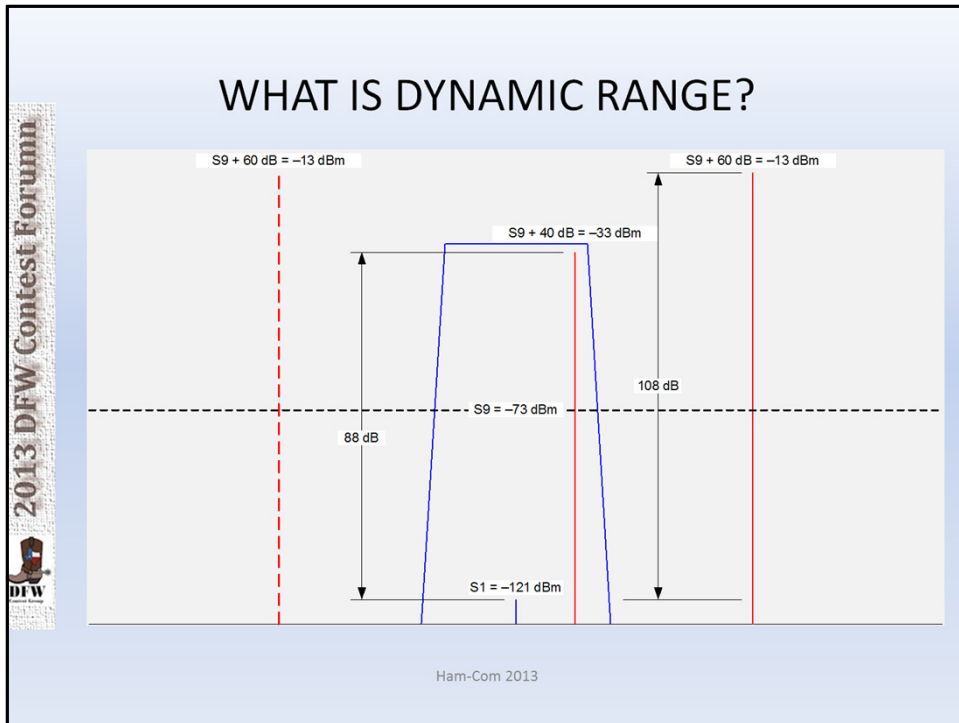


GO GET 'EM! Questions?

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Following slides are for backup



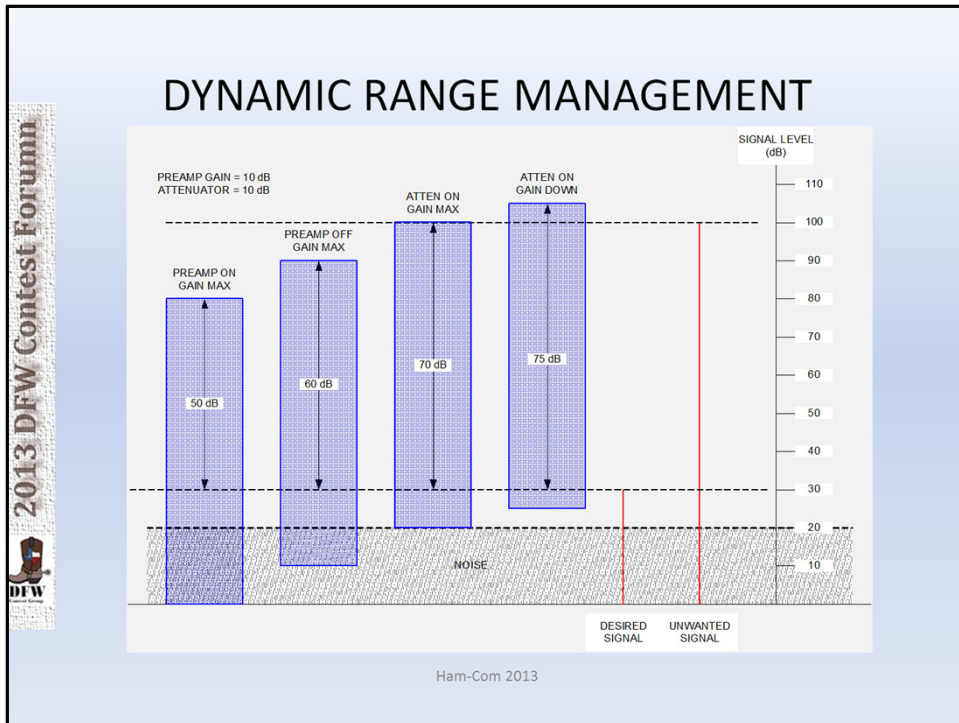
Dynamic range is the difference between the weakest and the strongest signals a receiver can handle simultaneously. It is expressed in dB.

The top of the dynamic range is determined by the maximum signal the receiver can accept without producing intermodulation products that compete with desired signals, usually defined as the level that produces intermod products at the receiver noise floor. For well-designed receivers, the most vulnerable stage for intermod is almost always the first mixer, since it has to handle the widest bandwidth. A “Roofing filter” at the first mixer output keeps unwanted signal power into the following stages lower and thereby improves dynamic range. Within the receiver’s bandpass the desired signal is competing with the TOTAL unwanted signal power, including both real QRM and internally generated spurious products.

The low end of the dynamic range is nominally the receiver noise floor. Note that the low end of the dynamic range is likely to be determined by ambient noise, especially in urban areas. Better antenna systems also produce higher received signal levels, so receiver dynamic range requirements are more stringent for really big stations. Modest stations can usually do with less than the ultimate in receiver dynamic performance.

The two $S9 + 60$ dB undesired signals shown in the illustration can produce a third order product in the center of the passband as shown. This sets an upper limit on the

intermodulation performance of the receiver.



This diagram illustrates management of an assumed 80 dB available dynamic range. Vertical scale is dB above receiver noise floor. Ambient noise is 20 dB above noise floor. Wanted signal is 30 dB above noise floor. Unwanted signal is 100 dB above noise floor.

Careful adjustment of the receiver gain can take advantage of the full available dynamic range to match ambient conditions. Too much gain causes part of the receiver's dynamic range to be used up with amplified noise that contains no useful signal information.

HOW MUCH DYNAMIC RANGE DO WE NEED?

- CW requires as much as you can get
 - Typical high-end radios have about 80 dB
 - Current state of the art is about 100 dB
- SSB is limited by transmitter splatter (IMD)
 - Most “12V” radios are doing well to achieve –30 dB IMD (S9 signal with S4 splatter)

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CW signals are inherently narrowband, SSB signals broadband. High selectivity can be used on CW to reduce the number of interfering signals, but intermod products from strong signals outside the filter bandwidth will also compete with the desired signals. Clicky keying will cause a CW signal to occupy more than its share of bandwidth.

On SSB, arbitrarily narrow filter bandwidths can't be used without sacrificing intelligibility. Intermodulation products produced in the PA stage of SSB transmitters causes the transmitted signal to spread well beyond its intended bandwidth and interfere with desired signals even at relatively large frequency separation. IM trash can't be fixed by any kind of filtering at the receiving end.

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HOW DO WE MANAGE DYNAMIC RANGE?

- Turn the Preamp OFF
- Turn the Attenuator ON
- Ride the RF Gain
- Use minimal AGC
- Audio strip with lots of headroom

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Adjust receiver gain to keep the signals it must handle at or above the noise floor. Don't let the receiver AGC on band noise. Especially for CW, try to maintain some dynamic range in the audio output. This will let you differentiate between signals of various strengths within the passband.

DOCUMENT INTERCONNECTS

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Double Ten Terminal Wiring

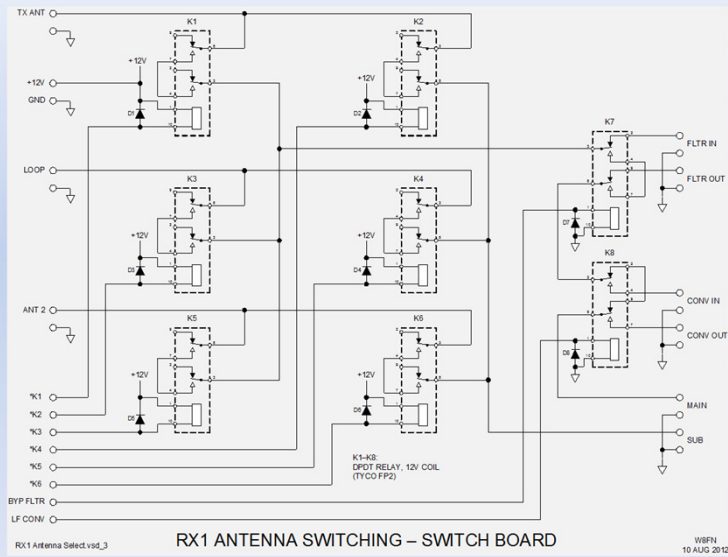
Pin #	Signal Name	Wire Color	Term Strip	Term #	Wire Color	Destination	Remarks
20	A1	Green/White	TS1	1	Black	Double Ten Switch A1	
21	A2	Green/Black	TS1	2	Brown	Double Ten Switch A2	
22	A3	Blue/White	TS1	3	Red	Double Ten Switch A3	
23	A4	Violet/White	TS1	4	Orange	Double Ten Switch A4	
24	A5	Gray/Black	TS1	5	Yellow	Double Ten Switch A5	Via interlock relay
25	A6	Black/White	TS1	6	Green	Double Ten Switch A6	
10	A7	Gray	TS1	7	Blue	Double Ten Switch A7	
11	A8	White	TS1	8	Violet	Double Ten Switch A8	
12	A9	Black	TS1	9	Gray	Double Ten Switch A9	
13	A10	Brown/White	TS1	10	White	Double Ten Switch A10	
1	+14V	Brown	TS1	11	Red	A/B Switch +12	
18	Ground	Pink/Black	TS1	12	Black	A/B Switch Chassis	
19	Ground	Yellow/Black	TS1	12	Tan, Pink	Double Ten Switch GND	
2	B1	Red	TS2	1	Black	Double Ten Switch B1	
3	B2	Orange	TS2	2	Brown	Double Ten Switch B2	
4	B3	Pink	TS2	3	Red	Double Ten Switch B3	
5	B4	Yellow	TS2	4	Orange	Double Ten Switch B4	
6	B5	Green	TS2	5	Yellow	Double Ten Switch B5	Via interlock relay
7	B6	Lt. Green	TS2	6	Green	Double Ten Switch B6	
14	B7	Red/White	TS2	7	Blue	Double Ten Switch B7	
15	B8	Red/Black	TS2	8	Violet	Double Ten Switch B8	
16	B9	Orange/White	TS2	9	Gray	Double Ten Switch B9	
17	B10	Orange/Black	TS2	10	White	Double Ten Switch B10	
8	*A SEL	Blue	TS2	11	Brown	A/B Switch A	
9	*B SEL	Violet	TS2	12	Orange	A/B Switch B	

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Example of tabular documentation of interconnection details

SCHEMATICS

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RX1 ANTENNA SWITCHING – SWITCH BOARD

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Example of schematic for custom hardware