Setting Audio Levels through a Repeater White Paper

A Step-by-Step procedure

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This White Paper describes the proper audio alignment procedure for WIN System repeaters and links, and may be useful to others who want good, clean audio through their repeaters and links.

Our WIN System Goals:

We on the WIN System, in order to achieve the best possible audio, strive to have as our goal maintaining the following Standards:

1) To achieve a 1:1 audio through-put on all WIN System Repeaters and Links.

2) To maintain an audio frequency response curve through our repeaters and links with a "flat" frequency response, to a maximum variance of +/- 0.5 dB (about +/- 10%) from the RX input through the repeater and/or link and out the TX output.

3) To make regularly scheduled trips to our repeater sites to maintain these standards.

Assumptions:

Our WIN System Standards above are based upon the following assumptions:

1) All measurements are made using a 1000 Hz audio tone as a reference audio signal or test tone. The only exception is the Palomar Telecom RBC-700 Controller, which has an internal 1064 Hz notch filter through the audio path, and therefore a 900 Hz tone as a reference audio signal must be employed.

2) If your Repeater RX uses CTCSS decode, you should disable it. Our base measurements are made without using CTCSS in any way that may affect the noise floor of our adjustments. No PL on the repeater RX input. Period.

3) If your Repeater TX uses CTCSS encode, you should disable it. If you are using the Com-Spec TS-64 you should disconnect the YEL audio output wire from the TS-64ds going to your Repeater TX, or pin 2 on GE exciters, the CG Input.

4) Verify the test gear you are using for accuracy. Connect your Signal Generator output to your Service Monitor input and generate a full-quieting (must not contain *any noise* whatsoever, usually 1000 uv or more) on-frequency signal with a 1000 Hz audio tone at 3.0 kHz deviation from the Generator into the Monitor. Be certain that both Instruments agree on the deviation level. This is a critical step in measuring the performance of your repeater/link audio through-put.

   If there is a discrepancy between the instruments, the priority is given to the Monitor, to be certain the Monitor is reading 3.0 kHz deviation, and adjust the output level of the Generator to make the Monitor display 3.0 kHz deviation, noting the adjustment level differential necessary to be made in the Generator in order to achieve that 3.0 kHz reading on the Monitor.

   Write it down. You'll need it later.

5) Sweep the 1000 Hz audio test tone, from 300 Hz to 3000 Hz on your Generator, and note the Monitor's deviation readings during the sweep process. The Monitor's readings should remain at 3.0 kHz through the entire audio sweep test.

   If you can do the sweep test in 100 Hz steps it is best, however even 500 Hz steps would at least give you an idea of your repeater system's audio flatness. If your Monitor does not read a consistent 3.0 kHz during the audio sweep test, then adjust your Generator where necessary to achieve the desired deviation reading of 3.0 kHz on the Monitor at each frequency step between 300 and 3,000 Hz you are using, noting the adjustment necessary in the generator to achieve the 3.0 kHz reading on the monitor at all steps.

   Write them down. You'll need them later.

   This assures an accurate audio through-put test on the repeater/link under test.

   At a minimum, perform the sweep test at the following steps:

   Tone at 500 Hz at Generator = 500 Hz at the Monitor
   Tone at 1000 Hz at Generator = 1000 Hz at the Monitor
   Tone at 1500 Hz at Generator = 1500 Hz at the Monitor
   Tone at 2000 Hz at Generator = 2000 Hz at the Monitor
   Tone at 2500 Hz at Generator = 2500 Hz at the Monitor
   Tone at 3000 Hz at Generator = 3000 Hz at the Monitor

<u>Receiver Set Up</u>

1) Make certain your Repeater RX is on frequency. You accomplish this by measuring the LO (Local Oscillator) frequency, which should be labeled on the RX ICOM. If it is not, take the operating frequency and deduct the IF frequency from it (GE is 11.2 MHz), eg: RX operating frequency is 448.900 MHz, *minus* the IF frequency of 11.2 MHz = 437.700 MHz for the LO.

   If it is a High-Side injection crystal, you must *add* the IF frequency to the operating frequency to get the LO frequency, eg: RX operating frequency is 448.900 MHz, plus the IF frequency of 11.2 MHz = 460.100 MHz for the LO.

   Net, or adjust, the crystal to the proper LO frequency. This sets your receiver operating frequency to the proper frequency.

2) Disable the CTCSS requirement at your Repeater.

3) Turn OFF the CTCSS (PL) on your source radio or Signal Generator.

4) When we ask you to inject a *full-quieting* signal into the Repeater RX, be certain there is *<u>no noise</u>* on the signal. That is what full-quieting means… No Noise. Typically this is 1,000 micro-volts (uv), or -47 dBm at a minimum.

5) When we ask you to inject an *on-frequency* signal into the Repeater RX, be certain that it is the correct RX operating frequency. That is what on-frequency means…

<u>Transmitter Set Up</u>

1) First, we need to measure the amount of noise contributed by the transmitter itself. Inject a full-quieting, on-channel signal into the RX with your signal generator. Then connect your service monitor to the TX operating on the correct frequency. Then turn *<u>off</u>* the 1000 Hz tone generator so no tone is being sent into the RX. Also be certain you are *<u>not</u>* generating a CTCSS tone into the RX. Then carefully measure the deviation of the TX. If necessary, ground the Mic and the CTCSS input lines. The TX always generates a small amount of noise that can be measured, typically around 0.05 to 0.15 kHz of deviation, with no audio present on the audio inputs (Mic and CTCSS). This deviation must be added to all future measurements on the TX. Write it down. You'll need it later. Repeat this process for all transmitters connected to the controller.

2) Next, we need to be certain the TX is *not* sending out a CTCSS tone, by either de-soldering the YEL CTCSS wire to the exciter at Pin 2, or by cutting it. If this is not possible, carefully measure the CTCSS deviation and add this number to the target deviation levels specified in this procedure. For example: If the CTCSS deviation is 600 Hz and the target audio deviation out of the TX is 3.0 kHz, the corrected deviation will be 0.6 + 3.0 = 3.6 kHz. Also, it should be noted that CTCSS and program audio do not simply add together well, so it would *really* be a lot better to disable the CTCSS on the TX.

3) Finally, we need to set the absolute maximum deviation the TX can make, by adjusting the Clipper on the exciter. In a GE MASTR II this is the on-edge pot (potentiometer) that is vertically mounted near the crystal ICOM. The other on-edge pot is closer to the RF output connector, and is the CTCSS level adjustment pot. Inject a full-quieting, on-channel signal into the RX with your signal generator.

   First you need to clean the two pots, as they get rather dirty, and they are about 30 to 40 years old! So, I usually carefully clean the two on-edge pots with a good contact cleaner (be sure the power is off) then rotate the pots from minimum to maximum several times to clean the windings. Then set the pot to about the middle setting.

   Then connect your service monitor to the TX, on the correct frequency. Then turn on the 1000 Hz tone on your Generator, and set your deviation for 7-8 kHz into the RX. Then turn up the RX level adjustment pot on the controller to maximum, and also the TX level adjustment pot on the controller to maximum. We want to get as much audio into the Mic line as possible. Note the deviation level coming out of the TX, and set it to the maximum deviation level you want your transmitters to operate at. We usually run our TX clipper deviation at somewhere between 5.0 and 5.5 kHz. This sets your overall maximum deviation level for the TX. Repeat this process for all transmitters connected to the controller.

Controller Set Up

Receiver Audio Path:

In multiple repeater/link radio sites, where there is more than one radio, it is critical to get the RX audio level set at exactly the same level's for all RX's and input devices to the Controller. To do this, we send a full-quieting, on-frequency FSD signal into the RX (FSD is Full System Deviation, or 5 kHz) with our Signal Generator. Most controllers have an audio test point. You will need an oscilloscope to perform this step.

1) First, you need to deal with pre-emphasized or de-emphasized audio from your receiver(s) to your transmitter(s). If you are using GE MASTR II radios, the GE exciter is a phase modulated transmitter, meaning that it automatically pre-emphasizes the audio at a 6 dB per octave rate. So, in order for the audio to sound correct you must de-emphasize the audio coming into the transmitter(s) somewhere in the audio chain before it gets to the transmitter.

   As we normally use discriminator audio out of our receivers, and it is not de-emphasized, we must de-emphasize it somewhere. If you are using an MOT fast-acting Squelch Board, you can order them with C-18 installed (a .01 mf cap), and you will have perfectly de-emphasized audio. Or, you can install C-18 yourself. Or, you can grab de-emphasized, squelched audio from the RX; however the stock squelch crash is really annoying.

   The bottom line is that you must de-emphasize the incoming audio somewhere before it gets to the transmitter. If you are using an FM transmitter, then it will not pre-emphasize the audio automatically, unless it does this in the low-level audio section. Check your manual to determine if your transmitter pre-emphasizes the audio or not. If it does not, then you do not need to de-emphasized the audio ahead of the TX as it is already pre-emphasized by the users radio, and discriminator audio does not normally de-emphasized the users audio. The bottom line here is that the audio coming out of the connected repeater or link transmitter must be pre-emphasized, either by the user or by the TX.

2) Next, determine where you are going to de-emphasize the discriminator audio coming from your RX, if you need to de-emphasize it at all. If you have not already de-emphasized the RX audio ahead of the controller, then it needs to be done by the controller at this step. Most controllers have an audio de-emphasis circuit in them, and you will want to use that circuit now (some work better than others).

3) After you have chosen your audio de-emphasis scheme, inject a full-quieting, on-channel signal into the RX with your Signal Generator. Find the input audio test points for each port on your controller (if none exist use the de-emphasis jumper as a test point). Set the tone generator at 1000 Hz with an FSD signal (5 kHz) and set the RX 1 input level pot on the controller such that the port 1 audio test point is at 2.0 volts peak-to-peak at FSD on your Scope.

4) Repeat this very important step with all RX's and audio input sources on each port to the controller, such as IRLP audio, for instance. They should all be the same 2.0 volts p-p with FSD at the audio test point for each port used.

Transmitter Audio Path:

1) Once you have all the RX input levels to the controller properly set at 2.0 v p-p for FSD, then inject a full-quieting, on-channel signal into the Repeater RX 1 with your Signal Generator. Then connect your Service Monitor to the output of TX 1 on the correct frequency. Then turn on the 1000 Hz tone generator, and adjust the deviation level of your generator to 3.0 kHz of deviation. If you still have your Scope hooked up, you should see 1.2 v p-p at the controller RX 1 test point.

2) While observing the TX 1 deviation, adjust the controller TX 1 audio adjustment pot for 3.0 kHz of deviation out of the TX, plus add in the TX noise contribution you wrote down earlier; let's say it was 0.15 kHz, so the total deviation reading on your Service Monitor should be 3.15 kHz. Your repeater audio through-put on port 1 is now properly adjusted. This assumes you are not running CTCSS on the TX output. If you are, then it needs to be disconnected for this step, or added to the target TX deviation. Please remove the CTCSS though if possible, as the program audio and low frequency audio really do not add well together very well. Disconnect the PL. If you are running CTCSS on the TX output, be sure and add it into this level adjustment also, or 3.0 + 0.15 + 0.500 = 3.65 kHz.

3) Be sure to add or subtract any differences (if any) that you measured and wrote down when you previously verified your test equipment to 2 above.

4) The next item is the sweep test, to verify your frequency response through the repeater and/or links. With the set up outlined in steps 1, 2 & 3 above, turn the frequency control for the audio from 100 Hz to 3000 Hz in 100 Hz steps, or 500 Hz steps, and note the TX deviation at each audio frequency step. Again 100 Hz steps are preferred; however 500 Hz steps would still give you some idea of the audio through-put flatness.

   It should not vary more than 10% throughout the entire audio band, 300 to 3000 Hz. At 3.15 kHz of output deviation, that would be 0.315 kHz up or down from your 3.15 kHz starting point at 1000 Hz, or 2.835 kHz to 3.465 kHz TX output deviation for a 3.0 kHz RX input.

   After you have measured the audio through-put at 300 Hz tone, move the frequency to 400 Hz, and note the TX output deviation. Repeat this step every 100 Hz, or 500 Hz, and plot the data.

5) Once you have completed this sweep test, including any adjustments you had to make for any differences you noted during the preliminary verification test of the test equipment above, you will have a good idea of just how flat your audio will sound. The practical limits are +/- 10% from the center deviation, or in this case, 3.15 kHz TX deviation. This is the step that makes for a great sounding repeater.

6) Repeat the above set up and testing for all TX's, fed by all RX's and audio sources. I usually leave the Monitor on the port 1 TX, and move the signal generator to the other inputs being used on the controller, making sure we get the same deviation results… 3 kHz IN = 3 kHz out. Then move the service monitor to the next transmitter, and repeat the audio through-put tests beginning the port 1 Repeater RX and moving through all the other RX's feeding that TX.

7) If you are running CTCSS on the output of any of your TX's then we will now adjust it. Remember that we must include the noise contribution of the TX itself in this adjustment. The average deviation for CTCSS is between 400 and 600 Hz for the CTCSS output tone deviation level. That means on the low side it would be 0.400 + 0.150 = 0.550 kHz (if your TX noise contribution was .15 kHz). You can adjust the on-edge pot closest to the RF output on the exciter. On the high side it would be 0.600 + 0.150 = 0.750 kHz. You now have your TX CTCSS adjusted. Repeat this process for each TX running CTCSS on its output.

Tones and Courtesy Beeps

WIN System standard is about 1 kHz deviation for your IDer tone. Your courtesy tone will probably be a little less that 1 kHz in deviation as the duration of the tones comprising the courtesy tone is usually somewhat less than the CW characters of your ID. This 1 kHz deviation is clearly a subjective number, and can be altered by your tastes, however a loud courtesy beep can surely be annoying when it blasts over, and possibly covers up, program audio. So keep it low enough to be heard, but not over-powering. The requirement is that it needs to be understood by the FCC, so no louder than that.

Audio Adjustments for the Palomar Telecom RBC-700 Controller

Initial Setup Parameters

First we need to set the absolute maximum deviation that each transmitter connected to the controller can possibly deviate, by adjusting the Clipper on each TX. In a GE MASTR II this is the on-edge pot (potentiometer) that is vertically mounted near the crystal ICOM. The other on-edge pot is closer to the RF output connector, and is the CTCSS level adjustment pot.

Inject a full-quieting, on-channel signal into the Repeater RX with your Signal Generator. Then connect your Service Monitor to the TX on the correct frequency. Then turn on the 900 Hz tone (NOT 1000 Hz), and set your deviation for 7-8 kHz into the RX. Then, turn the RX audio adjustment pot to maximum, using the P1 audio adjustment pot on Audio Mixer Card 1 (AM1), this is the top pot on the card, to maximum (remember it is a 20-turn pot). Then, adjust the TX audio adjustment pot to maximum, using the Master Gain pot, P8 on the Audio Mixer Card 1 (AM1). This is the bottom pot on the Card, and the left-most Audio Mixer Card. We want to get as much audio into the Mic line as possible.

Note the deviation level coming out of the TX, and set it to the maximum deviation level where you want your transmitters to operate at. We usually run our maximum TX clipper deviation at somewhere between 5.0 and 5.5 kHz. This step sets your overall maximum deviation level for the TX.

Repeat this procedure for each transmitter connected to the controller in the system.

In the controller, the Initial Setup Procedure must be performed prior to adjustments of any audio levels. This setup determines the overall gain setting. This is necessary because the Tone Buss is a non-adjustable fixed level audio buss.

This procedure assumes that the receiver and transmitter have been properly compensated for flat audio response, meaning we want discriminator audio from the RX fed into the controller. Discriminator audio is naturally pre-emphasized by the user's radio; however we do not treat the audio as it goes through the controller. We leave it alone, and if you are feeding a phase-modulated TX, like the GE MASTR II, then you must populate it's Audio Mixer Card with C1 to de-emphasize the audio just prior to going to the TX.

This procedure also assumes the Auxiliary Tone Buss modifications have been made to the Audio Mixer Card.

Perform the following setup procedures in the order that they are listed. Changing the order may result in the final audio levels not being set to the proper deviation.

Repeater Setup Procedure

1) Send the 'Interface Normal' command and trip the Interface Telemetry by momentarily providing a signal to the Repeater receiver input. This provides the normal audio load to the CW ID audio.

2) Send the 'Start Identifier' (*868) command or the 'CW ID to Repeater Only' command and adjust the tone deviation to 1 kHz deviation at the TX using the Master Gain pot, P8 on the Audio Mixer Card 1 (AM1). This is the bottom pot on the Card, and the left-most Audio Mixer Card.

3) If this deviation level cannot be reached, DO NOT increase the software volume level. Either change the way the transmitter is fed or increase the value of the 1 megohm feedback resistor on the U6 summing Op Amp on the Audio Mixer Card. This is the resistor just to the right of C1. The value should not be any higher than necessary, but in no case should it be higher than 3.6 megohms. If the transmitter is unusually sensitive, reduce the value of the 1 megohm feedback resistor or attenuate the level at the transmitter.

NOTE: After a power on reset or a software reboot, the CW ID the CW will sound loud and clicky. The deviation will be approximately 1.5 kHz to 1.8 kHz until the Interface Telemetry is tripped. The CW ID will return to the normal level after the Interface Telemetry has been tripped.

4) Send the 'CW ID to Interfaced Links' (*869) command and adjust the interfaced CW ID to 2.5 kHz deviation using the Tone Buss pot, P7 on the Audio Mixer card 1 (AM1). This is the second pot up from the bottom of the Card. Expect this pot to be close to its maximum gain value. If you desire the level to be lower, adjust the level using the CW Telemetry software volume adjustment after all the levels have been set.

NOTE: The "A" series Audio Mixer cards may not be able to obtain the proper CW Telemetry level. If this happens, leave the pot in the maximum gain value and continue with the adjustment setup.

5) Step 4 should be repeated for all Link transmitters on the controller. Send a *869 command and adjust the interfaced CW ID to 2.5 kHz deviation using the Tone Buss pot, P7 on the Audio Mixer card 1 (AM1). This is the second pot up from the bottom of the Card. Expect this pot to be close to its maximum gain value. If you desire the level to be lower, adjust the level using the CW Telemetry software volume adjustment after all the levels have been set.

Receive Audio to Transmitter Audio Setup Procedure

This setup must be performed after the "Repeater Setup parameters" procedure has been performed.

1) All levels are set using a ***900 Hz*** reference audio signal, or test tone. Do NOT use a 1000 Hz reference audio signal. The notch filters in the controller will slightly attenuate the 1000 Hz tone audio level as it passes through the controller.

2) Be sure and take all receivers using CTCSS out of decode mode and set all levels <u>without</u> the CTCSS active.

3) Be sure and take all transmitters using CTCSS out of encode mode. This is a must, as these measurements must be performed <u>without</u> PL on RX or TX.

4) Set the controller Power Switch to "Off." Remove the first (of two) Squelch Card (SQ1), insert an extender card, and insert the SQ1 card into the extender card. Turn the controller Power Switch to "On" and wait for the controller to boot up. Be certain that <u>***all***</u> CTCSS circuitry is off.

5) Inject a full quieting, on channel signal into the Repeater RX. Set the reference audio signal of the Signal Generator to *900 Hz* (NOT 1000 Hz) and set the deviation to FSD (5.0 kHz) into the RX. Using an oscilloscope, check the amplitude of the audio signal at TP1 on the squelch card and adjust the Level Adjust pot for 'port 1' to 2 volts peak to peak on the scope.

6) Repeat this procedure for each receiver in the system, verifying the appropriate Squelch Card test point and adjusting the appropriate Level Adjust pot for 2 volts p-p. Turn the Power Switch off and remove the card extender from SQ1, and replace SQ1 in its normal position.

7) Next we need to measure the amount of noise contributed by the transmitter itself. Turn the Power Switch back on, wait for the controller to boot up. Inject a full-quieting, on-channel signal into the Repeaters RX with your Signal Generator. Then connect your Service Monitor to the TX on the correct frequency. Then turn off the *900 Hz* tone generator so no tone is being sent to the RX. Also be certain you are <u>not</u> generating a CTCSS tone. Then carefully measure the deviation of the TX. If necessary, ground the Mic and the CTCSS input lines. The TX always generates a small amount of noise that can be measured, usually around 0.05 to 0.15 kHz of deviation, with no audio present on the audio inputs (Mic or CTCSS). This deviation must be added to all future

measurements on the TX. Write it down. You will need it later. Repeat this process for all transmitters connected to the controller.

8) Inject a full-quieting, on-channel signal into the Repeater RX and while observing the TX 1 deviation, adjust the controller TX deviation, using the P1 audio adjustment pot on Audio Mixer Card 1 (AM1), this is the top pot on the card, for 3.0 kHz of deviation out of the TX, plus add in the TX noise contribution you wrote down earlier, let’s say it was 0.15 kHz, for a total deviation reading on your service monitor of 3.15 kHz. Your repeater audio through-put on port 1 is now properly adjusted. This assumes you are not running CTCSS on the TX output. If you are, then it needs to be disconnected for this step, or added to the target TX deviation. Please remove the CTCSS though, as the program audio and low frequency audio really do not add well together. Disconnect the PL. If you are running CTCSS on the TX output, be sure and add it into this level adjustment also, or 3.0 + 0.15 + 0.500 = 3.65 kHz.

9) Next we will adjust the next receiver’s audio into the Repeater TX (Repeater port). Move the signal generator to the next port (Link port 1, usually) and inject a full-quieting, on-channel signal into the Link port 1 RX, and while observing the TX 1 deviation, adjust the controller TX deviation, using the P2 audio adjustment pot on Audio Mixer Card 1 (AM1), this is the second pot down from the top on the card, for 3.0 kHz of deviation out of the TX, plus add in the TX noise contribution you wrote down earlier, let’s say it was 0.15 kHz, for a total deviation reading on your service monitor of 3.15 kHz. Your link-to-repeater audio through-put on port 1 is now properly adjusted. Repeat this process for each input port to the Repeater TX.

10) Next we will adjust the next Link TX output deviation. Move the signal generator to the repeater port and inject a full-quieting, on-channel signal into the Repeater 1 RX, and while observing the Link 1 TX deviation, adjust the controller TX deviation, using the P1 audio adjustment pot on Audio Mixer Card 2 (AM2), this is the top pot on the card, for 3.0 kHz of deviation out of the TX, plus add in the TX noise contribution you wrote down earlier, let’s say it was 0.15 kHz, for a total deviation reading on your service monitor of 3.15 kHz. If you are running CTCSS on the TX output, be sure and add it into this level adjustment also, or 3.0 + 0.15 + 0.500 = 3.65 kHz. Your repeater-to-link audio through-put on link port 1 is now properly adjusted. Repeat this process for each input port to the Link port 1 TX.

The Audio Mixer Card has nine (9) adjustment pots on it, eight (8) on the top, and one closest to the bottom. They are all 20-turn pots, for maximum adjustment control.

The Bottom pot is the over-all TX audio adjustment for that port, with one Audio Mixer Card per port, maximum of seven (7) ports. We use it to properly adjust the CW tone level from the tone buss, as the tone buss is not adjustable, Once that is done, then each receiver is adjusted to the transmitter, and each transmitter has a separate Audio Mixer Card. There are seven (7) Audio Mixer Card slots in the controller, the right-hand seven slots.

The Repeater 1 Audio Mixer Card is always the very left-hand of the seven slots (or AM1).

The Link port 1 Audio Mixer Card is the next slot to the right (or AM2).

The Link port 2 Audio Mixer card is in the next slot to the right (or AM3).

The Link port 3 Audio Mixer Card is the next slot to the right (or AM4).

The Link port 4 Audio Mixer card is in the next slot to the right (or AM5).

The Link port 5 Audio Mixer Card is the next slot to the right (or AM6).

The Link port 6 Audio Mixer card is in the next slot to the right (or AM7).

Each Audio Mixer Card has eight (8) pots, each pot controls a port's input audio level to the transmitter in that port (1 through 7).

The top pot is the RX audio from Repeater 1 port adjustment pot.

The 2nd pot down is the RX audio from Link 1 port adjustment pot.

The 3rd pot down is the RX audio from Link 2 port adjustment pot.

The 4th pot down is the RX audio from Link 3 port adjustment pot.

The 5th pot 1down is the RX audio from Link4 port adjustment pot.

The 6th pot down is the RX audio from Link 5 port adjustment pot.

The 7th pot down is the RX audio from Link 6 port adjustment pot.

The 8th pot down is the Telemetry Tone audio adjustment pot.

The bottom pot, or 9th pot down is the TX Master Deviation Pot. It also adjusts the CW ID Level to each TX, so that is the level adjustment you should so first on each transmitter.

Remember, each transmitter gets an Audio Mixer Card.