1.0 Intro

We are Amateurs because we don't get paid to build our systems - resources are often scarce or unavailable. For this reason, we often make do with surplus equipment and alternate methods. In my case, a factory tuned duplexer was problematic and it was necessary to re-task a duplexer that was tuned to another part of the band as a replacement. This procedure is somewhat in line with a procedure in development by JagRF for use by Amateurs without expensive resources.

First, what is a duplexer? Because a repeater transmits and receives at the same time on frequencies relatively close to each other, a method is required to isolate these frequencies. Interference at the receiver by the transmitter must be mitigated. Simply stated, a duplexer is a cluster of resonant cavities connected in such a way as to separate the signals thereby preventing the transmitted frequency from reaching the repeater's receiver. This allows a transmitter and a receiver to operate on the same antenna at the same time.

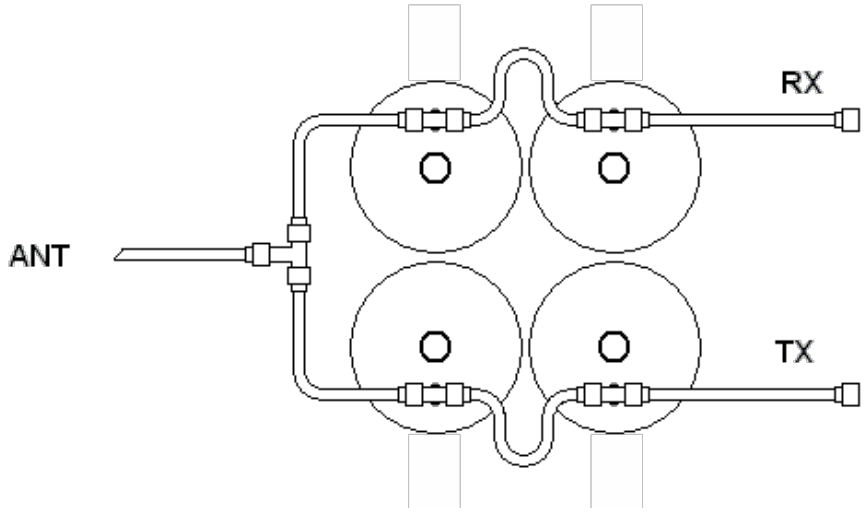

Figure A: 4-cavity duplexer

The Method described herein is for a BpBr duplexer without coaxial tuning stubs[1]. BpBr means Band-pass/Band-reject. This is a misnomer since it is really FpFr (frequency-pass and frequency-reject). One side of the duplexer passes the receive frequency and rejects the transmit frequency - the other side passes the transmit and rejects the receive.

Duplexers are best tuned by a spectrum analyzer with a tracking generator. These are expensive instruments - I don't have them. This monograph will describe a suitable method for getting a VHF or 70 cm UHF BpBr duplexer tuned well enough to use. This may work with higher frequencies but I have not tried it. This method is called 'tuning with power'. Understand that a duplexer tuned using this method can be improved somewhat by tuning with a spectrum-analyzer/tracking-generator. It should be noted here that the tracking generator is also tuning with power but it is a very low power. In this procedure, always use the lowest discernible power.

[1] This procedure does not address trimming tuning stub type duplexer although this method can be used for the band pass adjustment.

2.0 Use What we Know and What we Have

A duplexer cavity represents a 50 Ohm load with a flat SWR at a frequency within its frequency range of tuning. We can use these facts. We can use a mobile FM radio as a signal source, one or two forward/reflected-SWR type meters, and a dummy load. Here is my setup for a single BpBr cavity.

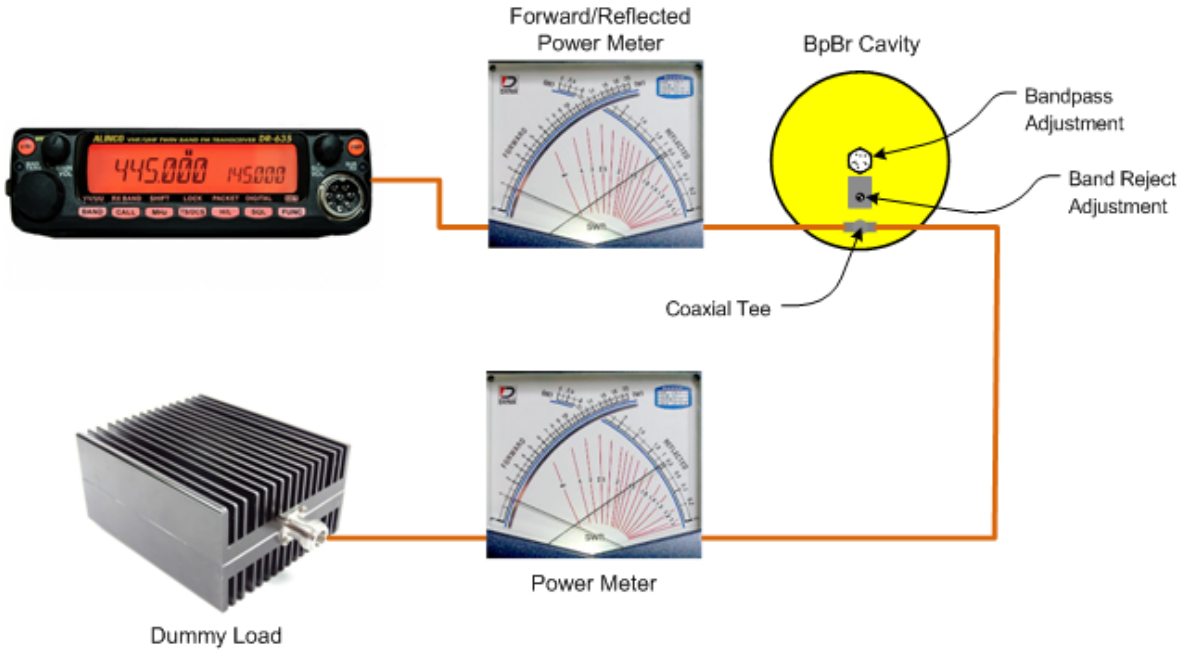

Figure B - Cavity Test Setup

Most hams have this gear laying around the shack or can borrow it. You can get by with one forward/reflected power meter by switching its position during the procedure. Also, the power meter in front of the dummy load does not need to indicate reflected power.

Important: Always use low power in this procedure - I recommend you do not exceed 5W especially when injecting the cavity's reject frequency. A duplexer's reject cavities may see reflected power in service due to antenna system mismatch but reflected power would seldom exceed 5W. Too much reflected power into a duplexer or too much power used in tuning could cause damage. For a repeater installation with high SWR - fix it at the source or use a circulator if you can't fix the source of mismatch.

Important: The ability of the meter on the downstream side of the cavity to measure small amounts of RF is critical. Consider an old CB SWR checker - they have a gain adjustment which can provide meter deflection for very small RF inputs.

Ensure that the dummy load size will handle the radio's output.

IMPORTANT: Read the End Notes section before you get started.

3.0 Single Cavity Procedure

Disconnect the duplexer wiring harness and set aside but note the orientation so that it can be reconnected in the same way. See End Note #1.

1. Setup per Figure B with the transmitting frequency of the radio set to the desired resonant frequency (pass frequency) of the cavity. Note: There is a lock nut or set screw on the band pass tuning shaft - ensure that it is loose. Use common sense - start out with the transmit power low and ensure that the meter scale exceeds the transmit power.
2. While transmitting, adjust the band pass shaft up or down until there is a sharp increase in forward power and a sharp decrease in reflected power (and SWR) on the input meter. Disregard the reading on the dummy load meter at this time. Note: Turning the shaft clockwise lowers the resonant frequency. Once resonance is reached, this adjustment becomes quite critical with only slight movements of the shaft peaking and dipping your meter. Again, you are looking for max forward, min reflected, which is lowest SWR. These indications happen together at the resonant frequency. Once the cavity is close to resonant frequency, you can increase the power output so that reflected power is more pronounced. I tune for minimum reflected power (lowest SWR) because this is in line with lowest insertion loss.
3. Set the transmitter to the frequency the cavity should reject and set the radio to low power (as low as possible and still get a reading but not to exceed 5W). While transmitting, adjust the band reject capacitor to show minimum on the output meter. Disregard the readings on the input meter. It is important to understand that the transmitter is now operating into a mismatched load. I use an older radio as a signal source and it has protection against reflected power. The best way to do this would be to use a tuned Circulator to protect your radio signal source but most Hams would not have this piece of gear.
4. The band pass adjustment may have been affected by the band reject adjustment so repeat Step 2 with the radio power adjustment to mid range or high.
5. Repeat Step 3 but adjustment probably won't be required.
6. Repeat Steps 1-5 for each cavity.

The duplexer wiring harness can be reconnected. Again, ensure it goes back on the same way it came off.

IMPORTANT: You are not finished. Make final adjustments to the assembled duplexer per Section 4.

4.0 Assembled Duplexer Procedure

I like to tune the duplexer with the RF going through the duplexer in the same direction as the RF would in service. That is, the received signal enters the duplexer at the antenna connection and the transmitted signal enters the duplexer at the other end on the TX side. See the setups below.

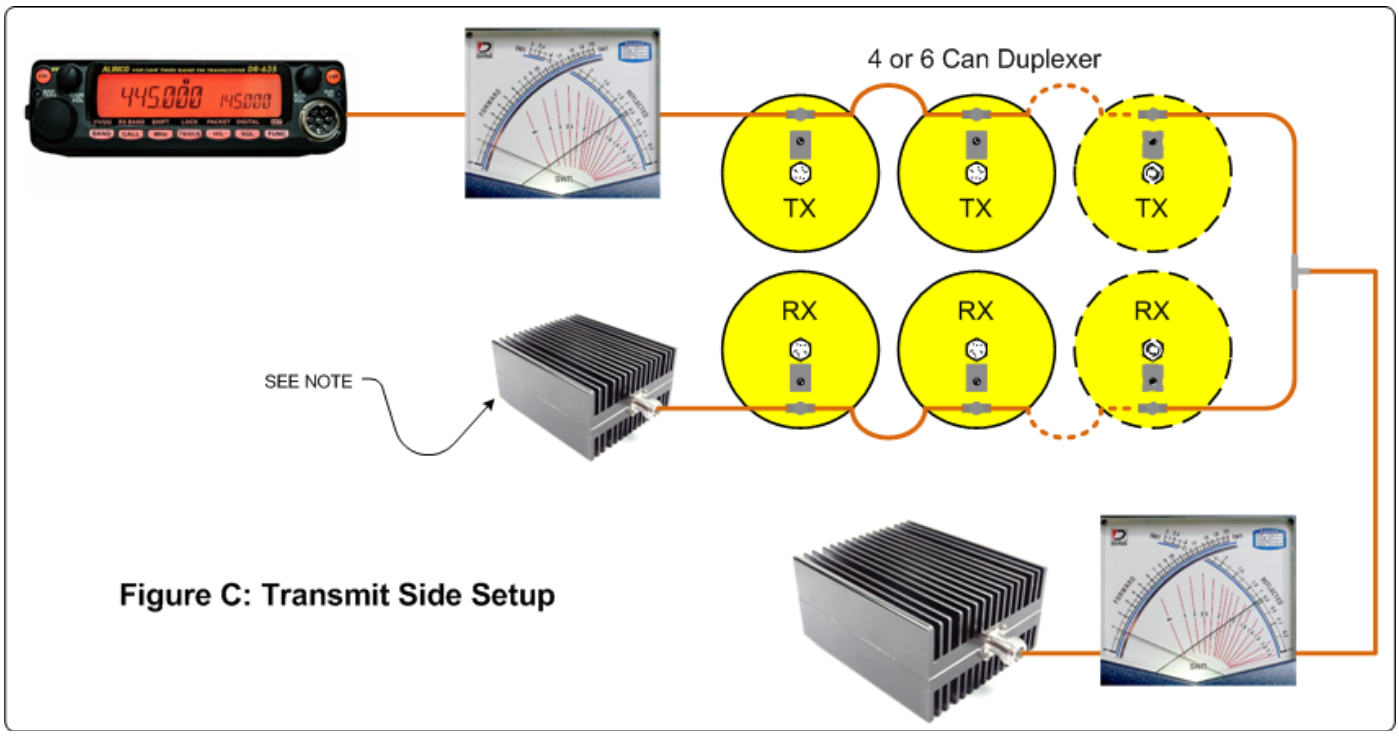

Figure C: Transmit Side Setup

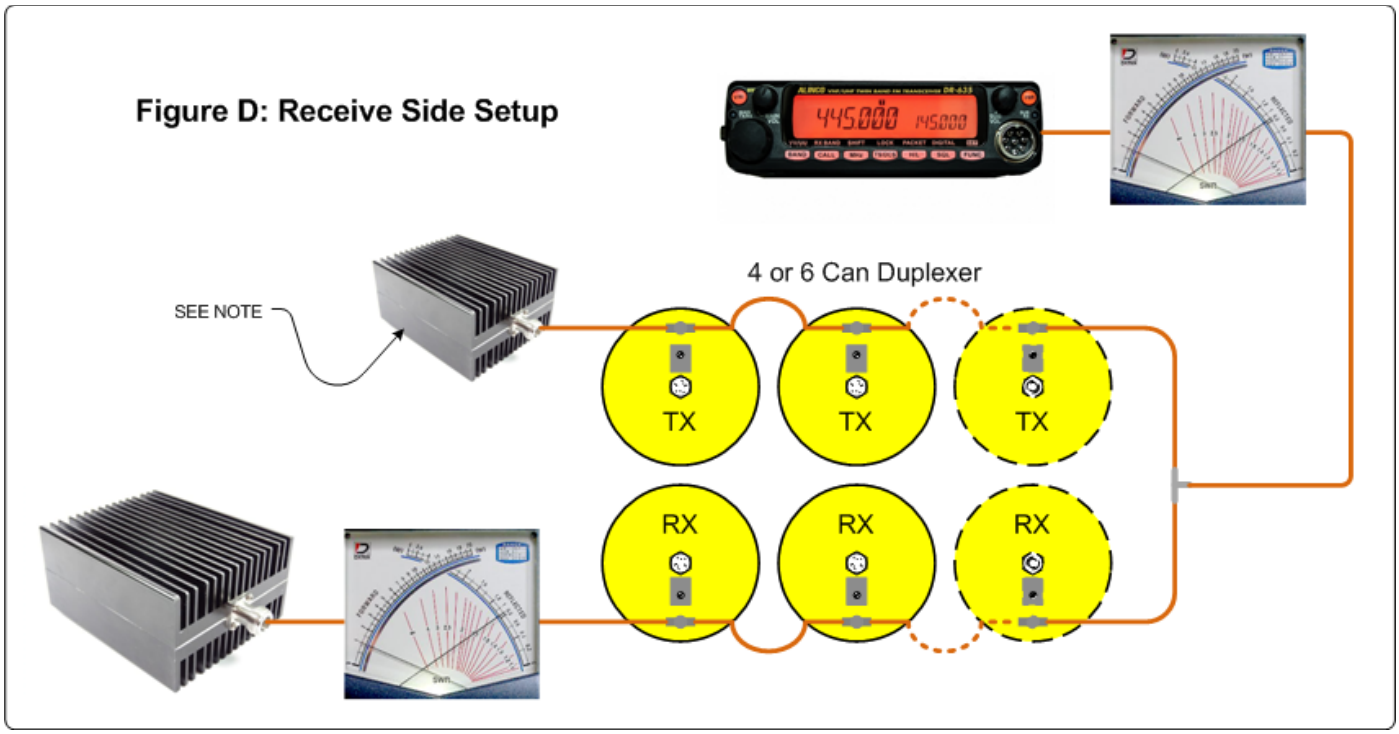

Figure D: Receive Side Setup

1. Setup per Figure C. **Note:** there is an additional component in this setup. A 50 Ohm termination is required on the opposite end of the duplexer. This may be a low power 'terminator' or it may be a dummy load. It does not need to have much of a power rating.
2. Set the Radio's output to low and only use the power required to get a good meter reading.
3. Set the Radio's frequency to the band pass frequency for the TX cavities. While transmitting and starting from the far end (right to left in Figure C), tune the band pass adjustment on each cavity for minimum reflected power on the input meter. Maximum power, minimum reflected power, and minimum SWR is what you are looking for. The minimum reflected power dip is probably easiest to see.
4. Setup per Figure D.
5. Set the Radio's output to low and only use the power required to get a good meter reading.
6. Set the Radio's frequency to the band pass frequency for the RX cavities. While transmitting and starting from the far end (left to right in the diagram), tune the band pass adjustment on each cavity for minimum reflected power on the input meter. Again, maximum power, minimum reflected power, and minimum SWR is what you are looking for, and the minimum reflected power dip is probably easiest to see.
7. This concludes the tuning. Lock down any tuning locks or set screws and ensure that protective caps for the reject capacitors are installed. Reject tuning will not be attempted with power.

5.0 End Notes

1. If your duplexer was manufactured for the 150 MHz or 450 MHz bands and is marked for these commercial frequencies, then the wiring harness cables are too short. The wiring harness is part of the tuned circuit, and the shorter coaxial jumpers will de-tune the final assembly somewhat. Recall that we tuned the cans individually first, and then we tuned as an assembly. If the coaxial harness is cut to the right frequency, then Band Pass adjustments for the final assembly should be nil to minimal. I strongly recommend that you make or purchase jumpers of the correct length before Band Pass tuning of the duplexer assembly. If the harness is not cut to resonant lengths then the assembly tuning will vary considerably from the individual cavity tuning. This is not good. The jumpers are 1/4 wavelength tip to tip, but the length must be calculated considering the velocity factor of the coaxial cable used.
2. It is absolutely critical that all coaxial cable on and around the duplexer and out the repeater room be double shielded. I recommend military grade RG-214 for VHF. For UHF, the jumpers are quite short and so RG-400 is recommended. DO NOT USE LMR CABLES IN OR AROUND THE DUPLEXER. LMR cable can be used up the tower to the antenna but should never be used for harness jumpers or for connectors from the repeater to the duplexer.
3. If a diplexer is to be used to connect another repeater to a common antenna, do not use a diplexer with coaxial cable leads - only use a diplexer with coaxial connectors so that double shielded coax can be directly connected.
4. It is absolutely critical that all coaxial connectors on the harness and connecting to the repeater and antenna be of high quality. DO NOT USE THE CHEAP CONNECTORS FROM CHINA. Don't learn this lesson the hard way.
5. Some duplexers use 'Band Pass only' cavities that have one or two coaxial connectors. The band pass portions of this procedure may be used on these cavities ignoring the Band Reject procedures. If the Band Pass cavity has two coaxial connectors, simply connect the input meter to one connector and the output meter to the other.
6. Elements of this method may be used for mobile duplexers, but clearly mobile duplexers cannot be disassembled for single can tuning. I have successfully moved a mobile UHF duplexer from a commercial frequency to a ham frequency with this power method and bandpass tuning only. And yes, this is not perfect, but it did work. Power tuning will not work with a mobile VHF duplexer because of the 600 KHz separation in the Ham band. I have been able to get a mobile VHF duplexer to work on low power at a 1.2 and 2.0 MHz splits.
7. It is best just to use this method on a BpBr duplexer without tuning stubs - this was my only intent for this procedure.
8. I do not recommend this method for duplexers that will be running more than about 50W of power. Having said this, you could certainly check receiver desense and run as much power as this tuning method will allow. Receive desense should be checked if you can.

Once tuned, duplexers are quite stable and not sensitive to getting banged around a bit - be careful but no need to wear kid-gloves. Don't take short-cuts - use good connectors and coaxial cable. If there is a problem, it is usually a bad connector, a bad connection, or something loose. Old duplexers may be corroded internally - if this is the case, there is nothing to do but to repair or replace. A 'jumpy' meter reading during tuning is indicative of internal corrosion or a loose connection. Don't second guess yourself - follow this procedure and you are good to go. If there is a problem - it is not the tuning.