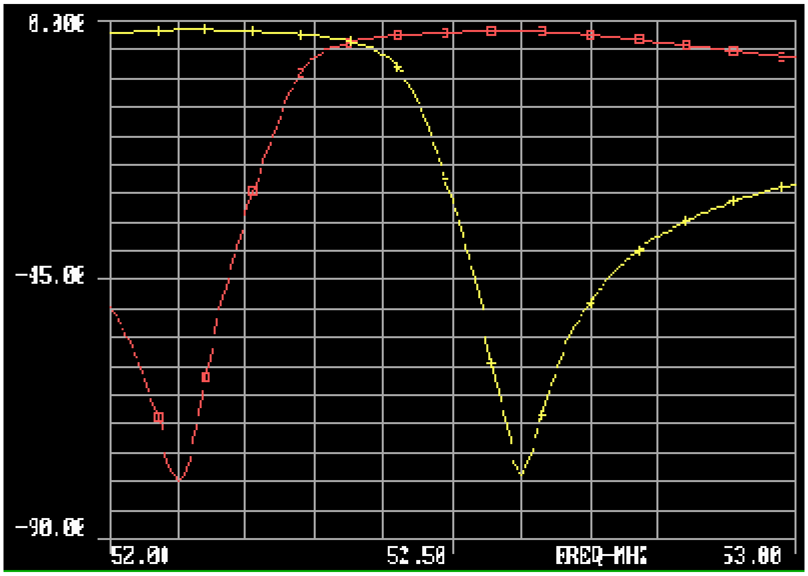
Updated 6-25-2003 15:00 UTC



6 Meter Duplexer

Six Meter Heliax Duplexer Design

Shown above is an overlay of the 1) receive-port to antenna-port and 2) transmit-port to antenna-port port S21 (Insertion Loss) plots for a typical 1/2 MHz split, 6-stub Heliax Duplexer.Additional plots and engineering data/parameters may be found below.

Section 1.0 General

This web page describes a ***Six Meter Duplexer*** designed by WB5WPA that physically consists of:

- **Six (or eight)** band-reject coaxial "stubs" fabricated from 1 5/8" Heliax stubs (read that as: "*one and five-eighths inch Heliax stubs*"). 1 1/4" ("*one and one-quarter inch Heliax stubs")* Heliax were used in developing the original prototype (which is still in service!) and results in slightly poorer RF performance than the larger diameter 1 5/8" Heliax.
- **Six (or eight)** 'gimmick' caps fabricated from (approx.) 3" lengths of RG/8, inserted in the Heliax stubs and forming a series-resonant 'tuning' capacitor. The final length is determined during the 'tuning' process.These 'gimmick' caps are a cost effective way of achieving high-Q, high operating RF-voltage caps without the expense of commercially purchased parts.
- **Six (or eight)** inter-connecting coax jumpers made of 1/4 Lamda (electrical) lengths of RG/58 cable. We have found it isn't necessary to use double-shielded RG58 cable at 6M frequencies.

- **Three (or four)** (each) Shunt inductors/capacitors. These serve to recover from the deep notch attenuation at the reject frequency as one approaches the 'pass' frequency.

The first ***proof-of-concept*** engineering unit I designed and built has proven itself over the last ~~five~~ (oops - it's ~~1997 1998 1999 2000 2001 2002~~ 2003 make that ~~six seveneight nine ten eleven~~ **twelve** years.

This original *prototype* duplexer I built used 1 1/4" Heliax (that's all I could find at the time) and exhibited the following key characteristics:

- **Half meg split** (.500 MHz repeater offset)
- **73** dB of attenuation and
- Approx. **1.5** dB of insertion loss.

Larger Heliax (such as 1 5/8") is recommended for a 1/2 MHz split because of the lower insertion losses that will be seen. Using 1 5/8" Heliax at the proper length also achieves a little more *notch* (attenuation) depth - with a corresponding lower IL (insertion loss) resulting in better than the 1.5 dB achieved by my first 1 1/4" Heliax design.

Changes in notch frequency due to temperature changes is negligible. I 'soaked' several stubs in cold (winter) and hot (summer) temps and could see no real appreciable change - this surprised me. I had to wait till the passage of those seasons since I don't own -and didn't at the time have access to- an environmental chamber large enough to test 1/4 lamda stubs. I'm a big believer in "testing over temperature".

Section 1.1 Duplexer Stub-Length Calculation.

If you're running Netscape 2.0x or greater, click here on Calculate lengthto run a short Javascript that will calculate the physical length of a stub constucted of Andrews LDF Heliax.

Section 2.0   1 5/8" Heliax Six Meter Stub Duplexers: Attenuation and Insertion Losses

Designs have been tested for 0.5 MHz and 1.0 MHz spacing (or 'split') repeater systems and the general performance specs for these two "splits" are shown below. For construction details (even though they are kind of specific to just my first design) read Section 3.0 titled "My First Six Meter Duplexer".

Now, a word about 'repeater splits'.

I favor the **1/2 MHz repeater split** on six meters because of the limited working bandwidth of practical antennas at these frequncies, especially the professionally built antennas like the DB Products folded ground plane and folded dipoles, antennas that will last and stand up to the effects of weather over time and don't generate broadband 'white noise' when excited with RF in a full duplex operation like some cut-down CB ground planes have been found to do. Others ignore the importance of the antenna and it's constuction - usually at their own peril. They may experience 'white noise' desense while the repeater transmitter is on the air, 'crackling' desense as the antenna ages and gets wet and 'popping' noises in the case of some non-DC grooounded antenna designs.

At six meters (50 MHz) a two-percent bandwidth specification on an antenna means the antenna has a *usable bandwidth* of 1 MHz where the match ('VSWR', RL, S11, etc) looks BEST in the *middle* of this 1 MHz range and slowly rises and passes through some value of VSWR (say, 1.7:1) at the edges of that bandwidth. *Any* duplexer will do 'best' into a flat, matched antenna (or load), so, to "keep your 50 Ohm system all 50 Ohms" -or at least nearly so- a matched antenna is really a requirement when working with a duplexer. (Long lost, I think, is the concept that any tuned circuit -including antennas- possess some finite figure of 'Q' that dictates it's inherent bandwidth thereby establishing it's workable frequency range. Remember, *there is no cheating nature at her own game*.)

In all cases below 36" physical lengths of RG-58 are used between stubs and to the BNC "tee" junction where the antenna is connected.

Section 2.0.1 RG-58 Electrical 1/4 wavelength Calculation

For Netscape 2.0x or greater users Calculate the length of the RG-58 inter-connecting cable. This figure will be the physical length of the RG-58 cables.

2.1 One-Half MHz split Duplexer Specs, 3 stubs/leg, 1 5/8" Heliax stubs

- Rcv Leg stub length: 44.4"
- Notch attenuation: 80 dB (at xmit freq)
- Insertion loss: 1.7 dB
- Xmt Leg stub length: 44.7"
- Notch attenuation: 86 dB (at rcv freq)
- Insertion loss: 2 dB

View the EESOF Touchstone Circuit file

2.2 One MHZ Split Duplexer Specs, 3 stubs/leg, 1 5/8" Heliax stubs

- Rcv Leg stub length: 44.1"
- Notch attenuation: 84 dB (at xmit freq)
- Insertion loss: 0.9 dB
- Xmt Leg stub length: 44.9"
- Notch attenuation: 83 dB (at rcv freq)
- Insertion loss: .85 dB

View the EESOF Touchstone Circuit file

Section 3.0 History of my first or *proof-of-concept* 6 Meter Duplexer

The duplexer described here was the result of an experiment to see what could be done with available materials (1 1/4" Heliax) and using simple hand tools for what seemed a worst case scenario: a 500 KHz ("half MHz") split (repeater offset) 'machine'. In the process I tested various stub lengths, made measurements and took those measurements back into Mathcad and then finally into EESOF's Touchstone to see what was ultimately possible.

The results have been meausured and verified with a variety of test equipment including an IFR 1500, Tektronix 7L12/7613 combo, HP 432, HP 606A an HP Vector Voltmeter.

Sec. 3.0.1 MathCad Analysis

These are screen captures of Heliax *line analysis* done in MathCad. If you can follow the math I calculate some acceptable IL (Insertion Loss) and notch depths values for 1/2" through 1 5/8" Heliax:

Screen 1
Screen 2
Screen 3
Screen 4
All screens together

An experiment was performed to validate the attenuation that may be seen using shunt elements (*across* rather than *in series with* a 50 Ohm line) and confirm the validity of the attenuation equations used in the analysis of the Heliax stub. Here are the results shown in 'MadCad' screen capture form:

Screen 1
Screen 2
All screens together

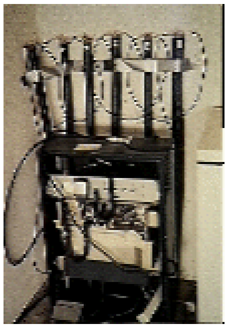
Sec. 3.1 Building one

If you wish to Build it (text doc) here is how I described it back then.

Sec. 3.2 Tuning it

If you wish to Tune it (text doc) here are a couple of techniques that can be used to tune it.

Sec. 3.3 Machines in Service w/Heliax duplexer

 GE MASTR PRO Six-meter 1/2 MHz xmit/rcv offset repeater

Click here for Big View of MASTR PRO repeater that has been in service on 52.21 (in) 52.71 (out) north of Dallas, Tx since 1991 using the first duplexer I built. We have also built machines using all Solid State radios such as Motorola Micors on a 0.5 MHz split and a GE MASTR EXEC II on a 1 meg split with no desense using the Heliax duplexer design.

Dan, N5MRG, has had several 0.5 and 1.0 MHz machines on the air - all with good results.

Sec. 3.4 Reducing Losses in Transmitter Leg

Single stubs have been successfully placed between the repeater's *exciter* and the *final amplifier* in an effort to reduce **exciter noise**.

Using this technique the losses normally incurred at the higher power when *all* the notch stubs are placed inline with the *output* of the final amplifier will be seen at the lower power level of the exciter. This can reduce losses in the transmit leg (and at the transmit power level!) by 1/2 a dB or more.

Sec. 3.5 Repeater split consideration

We favor the 1/2 MHz split because antennas can be nearly "in tune" for both receive and transmit frequencies. At 52.50 MHz a 2% frequency spread is 1.05 MHz. This means the Standing Wave Ratio should be less than 1.5 over this 1.05 MHz range and the RL (Return Loss - reflected power loss) should be around 14 dB.

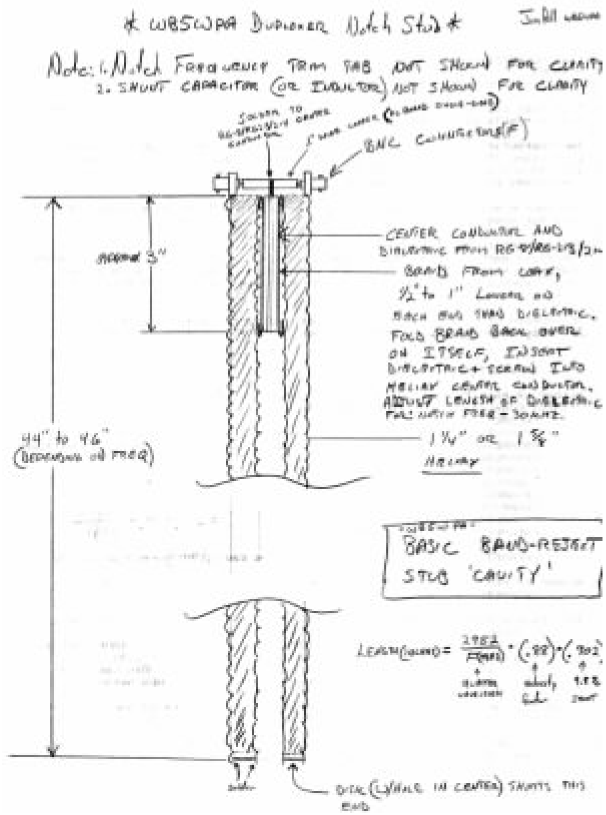
The one-half MHz spacing of 1/2 MHz split machine is well within the 2% frequency spread spec'd for most commercial antennas at six meters where the SWR is specified to be less than 1.5 (14 dB RL). Operating (centering) a 1/2 MHz split repeater as close to the center of this bandwidth should yield an SWR below 1.2 (about a 21 dB RL).

This says nothing of where the actual antenna impedance (Real + Imaginary) may lie on the Smith chart though. The *actual mismatch loss* could be much larger because a non-conjugal match could exist between the output of your duplexer and the antenna. As these Z values are highly field dependent on a number of factors trial and error with appropriate test equipment may be necessary for total optimization.

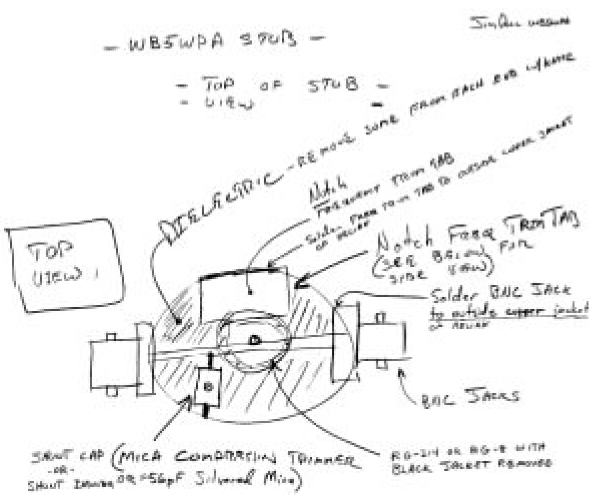
Sec. 3.6 Sketches, Images

The sketches are from my early *crude* notes

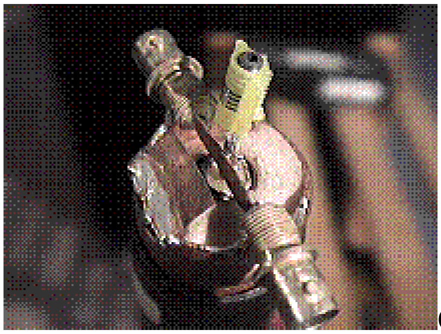
Schematic diagram of duplexer: [Schematic sketch]



Cutaway diagram of one stub Large: [cutaway view sketch (Acrobat Reader PDF format)]

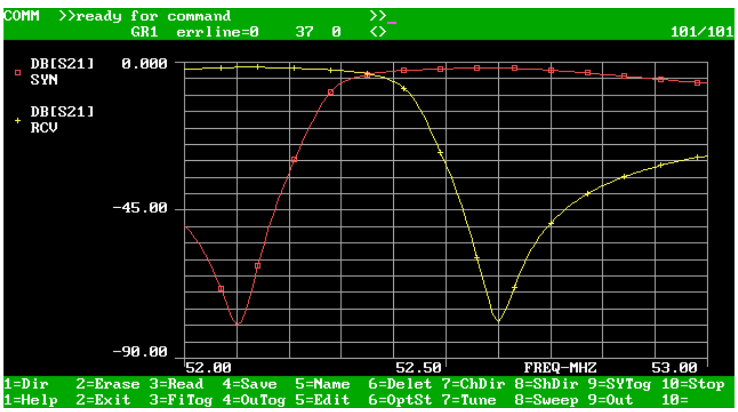


Top view; Close up of the top of the stub Large: [Top view sketch (Acrobat Reader PDF format)]

Close-up views of the top of a stub with an inductor. A Mica compression would replace the inductor on the other stubs.

Other pics: gif 1 , gif 2 , gif 3a , gif 4a , gif 5a

Sec. 3.7 RF Sweep



RF performance (IL or S21) of the Rcv/Xmit legs to Ant of a 1/2 MHz 1 5/8" Heliax duplexer

Full-size graph depicting the IL performance of the duplexer. This is taken from the common (or antenna) port to each of the 'legs' - the transmit leg and the receive leg - and depicts the IL (S21) from each of the legs (transmit and receive) back to the common antenna port.

Full-size graph depicting the isolation performance of the duplexer. This is taken from the transmit leg to the receive leg and depicts the isolation (measured via an IL or S21 measurement) the duplexer provides between receiver to transmitter with the antenna port terminated in a resistive 50 Ohm load (50-j-zero load).

Duplexer's can be built using slightly different parameters (lengths) to yield a little deeper notch or a little less notch - some radios (esp those with transistorized exciters and PA's) seem to be a little 'noiser'. For instance, Dan, N5MRG, found that he required four stub's per leg on a Motorola Micor radio, while only three stubs per leg were needed on a GE Exec II radio.

Duplexer design or website issues; e-mail Jim (callsign: WB5WPA) at jvpoll@dallas -dot-net (Be sure to remove the -dot- and spaces and replace with jusst a ".")

Dan, N5MRG, bay be available for questions or consultation by phone. Dan can be reached, days or evenings, at 972-782-6164. **Dan** at one time was *building duplexers* to the tune of **$500 US**. (All of Dan's units were fabricated using only 1 5/8" Heliax and are **Plug and Play** -no external tuning required- units.)

Please note that what Dan builds for sale differs *physically* from what is shown here but electrically is identical.The changes he made are for producability and ruggedness improvements - considerations not implemented during ***initial proof-of-concept and engineering development*** of the first duplexer I built and subsequently describe on this page.

e-mail received:

> Jim your design has been put to good use! Take a look at my website for
> further information. http://www.wa7x.com/ki7dx_rpt.html
>
> 73's,
> WA7X Glen
>

Back to
Technical Web page
Jim's Main Web page
Weather links Page

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