Updated 12-14-2004

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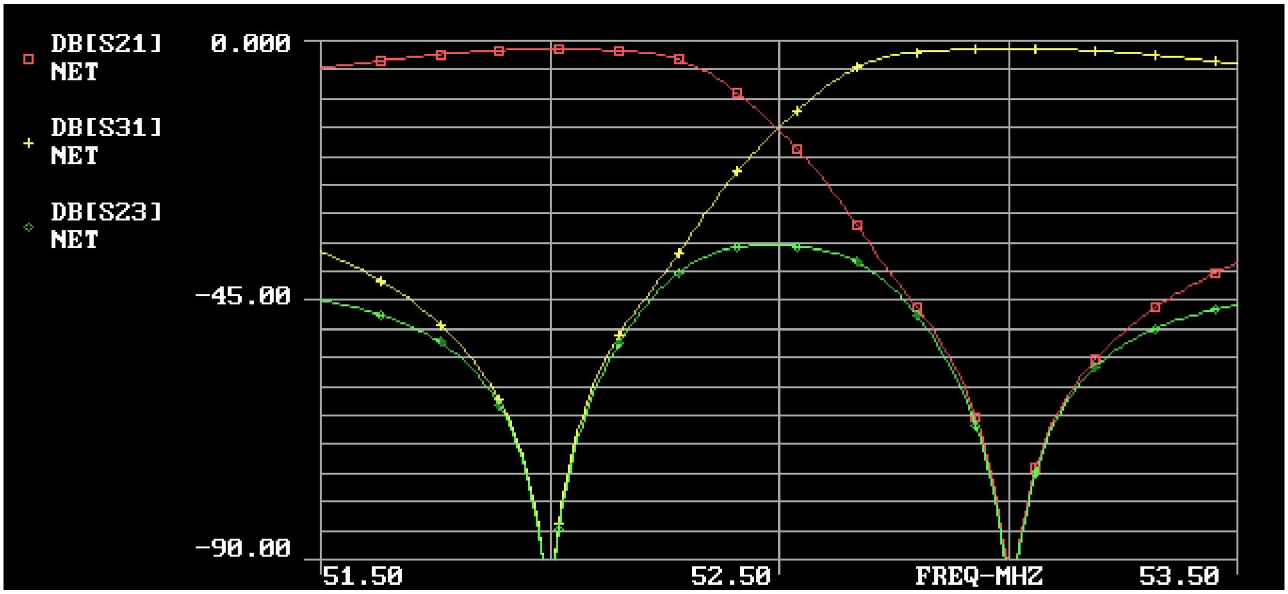
Six Meter *Hybrid Ring* Heliax Duplexer



Low-band VHF *Hybrid Ring* Heliax Duplexer Performance on 6 Meters

Shown above is a graphic displaying the performance of a Hybrid Ring Duplexer using a ***3rd generation design*** notch stub. This Hybrid Ring duplexer is a 1 MHz split, 93 dB Isolation, less than 1.5 dB Insertion Loss, ***4 stub*** Six Meter Heliax Duplexer operating on a 52 MHz in / 53 MHz out frequency pair.

Why a Hybrid Ring Duplexer? Two words: "Band pass". Utilizing a notch stub in a *Hybrid Ring* configuration yields a band pass function rather than the more usual notch or 'reject' function.

The graphic above shows the following "S21" S-Parameter sweeps for a 1 5/8" Heliax Duplexer using only 4 Heliax stubs:

1. S21 measurement, measured from the receive port to the antenna port (square/red line --------),
2. S31 measurement, measured from the transmit port to the antenna port (plus sign/yellow line --------) and
3. S32 measurement, the 'isolation' a duplexer exhibits from receiver to transmitter measured from the receive port to the transmit port (diamond/green line ---------).

The Insertion Loss in the 'passband' of this duplexer indicates to be less than 1.5 dB; this is excellent performance for a duplexer this size, this weight and form factor, especially when compared against some of the *cabinet-hoggers* and six-foot can designs that are doing service on VHF Low-band. S11 on each port is equally impressive; over 20 dB RL on each port (see further below for S11 sweeps).

This HR duplexer, modelled using 1 5/8" Heliax exhibits around 1.5 dB IL for the Xmit and Receive legs each at their respective 'pass' frequencies. *Experience has shown* that design (simulation/modeling) with such tools as Agilent/EESOF's Touchstone with the correct constants in the 'coax' line statement results in a design whose performance allies with the physical realization..

-- *Hybrid Ring* Circuit Configuration --

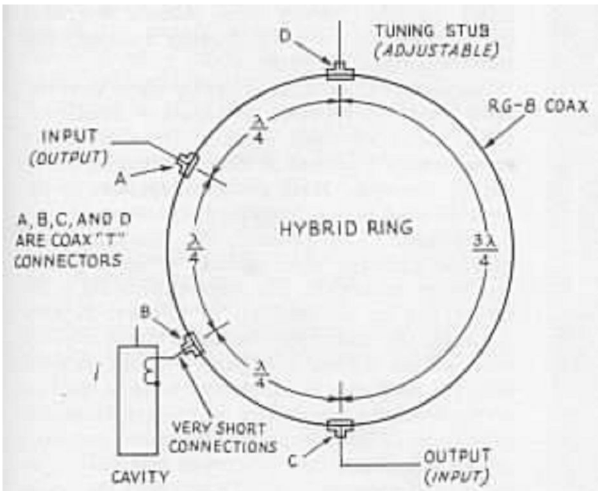


Fig. 7-9 — A hybrid ring with a tuned cavity attached. This type of circuit will pass energy at one frequency while greatly attenuating another. The shorted stub provides a means of "fine tuning" the system.

Q: What is a Hybrid Ring?

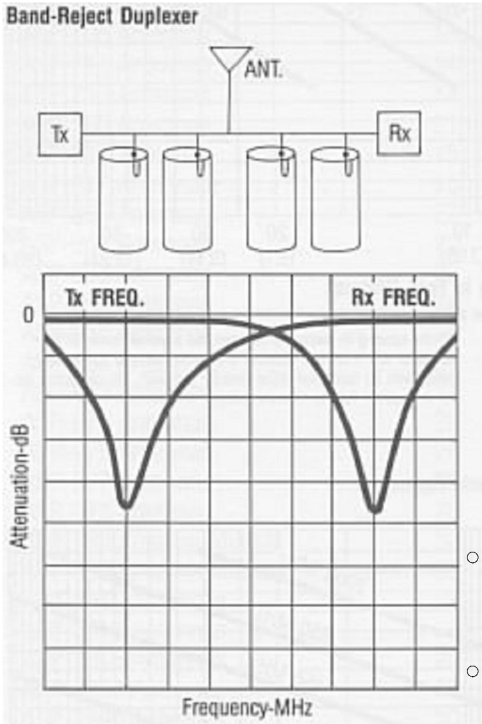
A: A 'Hybrid Ring' is an *electrically circular* configuration of coaxial cable that posseses certain electrical properties that enable electrical isolation to be achieved in a different manner than that achieved using the usual band-pass or band-reject circuit configurations.

A *Hybrid Ring circuit configuration* is used to turn a *notch element* into a *bandpass element* through the magic of *signal cancellation*; the total length around the ring is 6/4 (or **1 and 1/2**) wavelengths total. Now note the difference between the two 'path lengths' between the INPUT and OUPUT points: a) 1/2 wavelength going counter-clockwise past the CAVITY and b) **1 wavelength** going clockwise around the other way; if one sends a signal into the port labelled INPUT nearly total signal cancellation occurs at the port labelled OUPUT (assuming the CAVITY or stub is not present or active) because of the *total path length difference* is **1/2 wavelength**, and signals that are 1/2 wavelength (or 180 degrees) *out of phase* cancel (assuming equal amplitudes).

Now note the placement of the the 'cavity' (or notch stub) located midway between two points marked INPUT and OUTPUT; at the frequency the stub is tuned to, the 1/2 lamda 'path' is effectively 'shut off' by the *short* created by the notch stub between those two lengths of 1/4 wavelength cable; the short created by the stub also becomes effectively *an open* through the 1/4 wavelength cable at the INPUT and OUTPUT ports, and the 'signal cancellation' we had moments ago now goes away; the Hybrid Ring now exhibits a 'band pass' characteristic at the frequency the CAVITY (or stub in our case) is tuned to.

-- Duplexer Types --

In the world of duplexers, there are basically four different types:

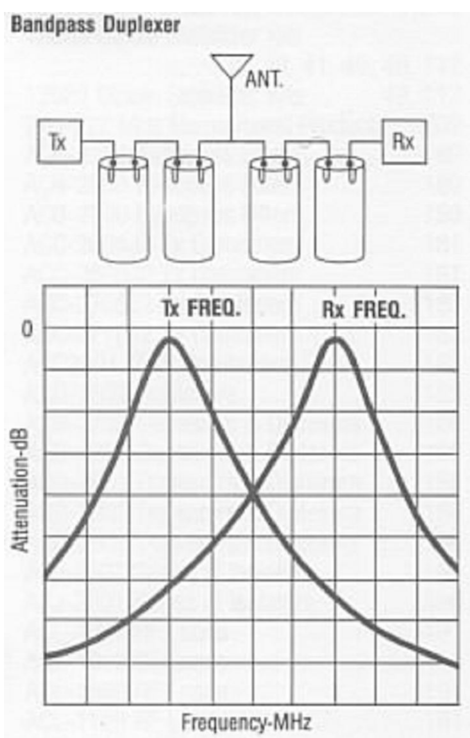


1) BR- Band Reject, also known as 'Notch Duplexer' built using tuned/resonant elements that 'notch' out one particular frequency in the receive and transmit legs.

A Band Reject (BR) type duplexer means that deep attenuation 'notches' are provided for 1) receiver protection (from the transmitter's output) as well as 2) transmitter noise (at the receive frequency). The attenuation of 'out of band' signals is less with a BR design than that achievable with a BP design (although there is *some* attenuation of 'out of band' signals with a BR design).

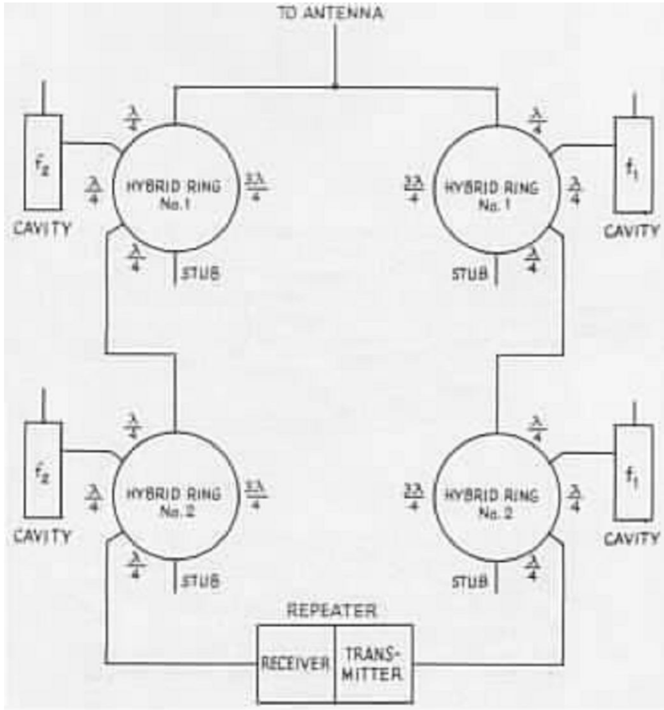
The benefits of BR duplexer designs are:

- Reduced insertion loss - lower IL values can be obtained than those of a BP design *given* the same 'Q' and number of resonators using either 'cavities' or stubs and
- BR duplexers are more suitable for close spacing 'splits' (repeater splits) when working with a small number of Q-limited (non-optimum Q value) resonant elements such as 1 1/4" or 1 5/8" Heliax Stubs.



2a) BP - Band Pass, built using tuned/resonant elements which 'pass' one particular frequency in the transmit and receive legs.

BP duplexers are especially suitable in frequency crowded areas and provide additional rejection of in-band and out-of-band signals. Although BP duplexers generally have a slightly higher IL than BR style duplexers often times it is worth the slight 'cost' of the additional IL for the protection afforded the receiver and the filtering done to the transmitter; sometimes the 'path' into the transmitter is a source of transmitter intermodulation with other nearby transmitters so the benefit of a BP extends there as well.



2b) BP - Band Pass, as realized in a Hybrid Ring configuration using tuned/resonant elements which 'notch' one particular frequency in the Hybrid Rings in the transmit and receive legs.

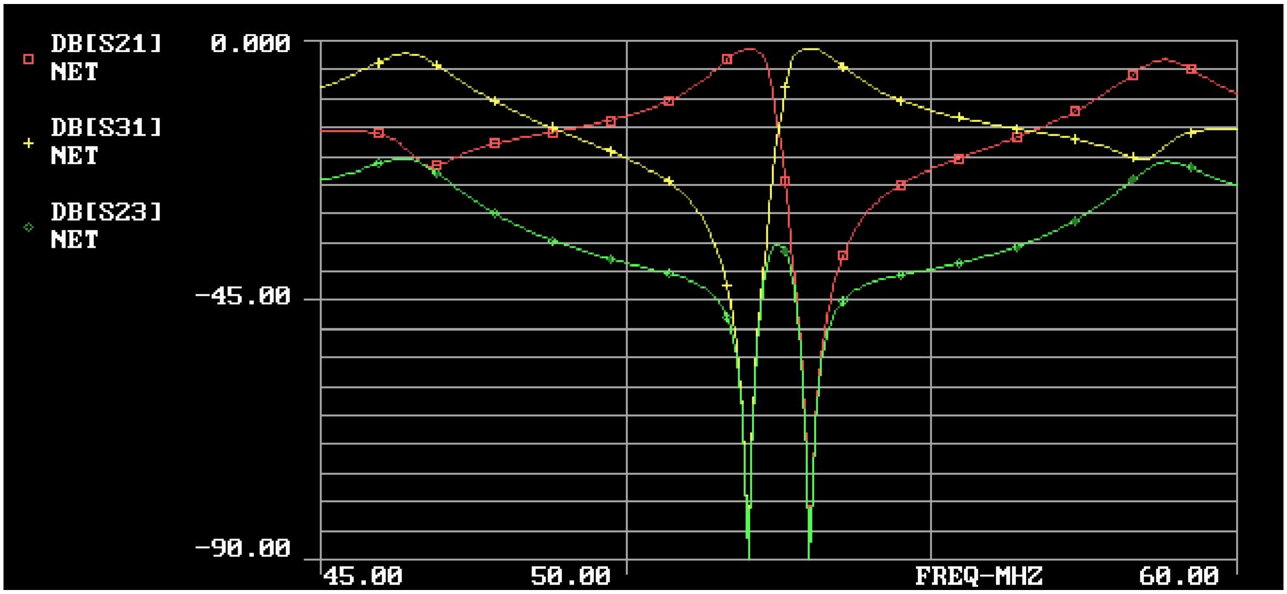
The image to the left shows how the four band pass Hybrid Rings (two for transmit and two for receive) are connected for use in a HR bandpass duplexer.

The length of cable to the common antenna port, although not shown, would be a 1/4 wavelength of cable from each Hybrid Ring to a common point (like a UHF or BNC 'Tee" connector) known as the Antenna Port.

3) BPBR - Band Pass Band Reject, a combination of the above

4) HPLP - High Pass Low Pass, built using high pass fitlers and low pass filters.

Band Pass Duplexer Performance - HR configuration

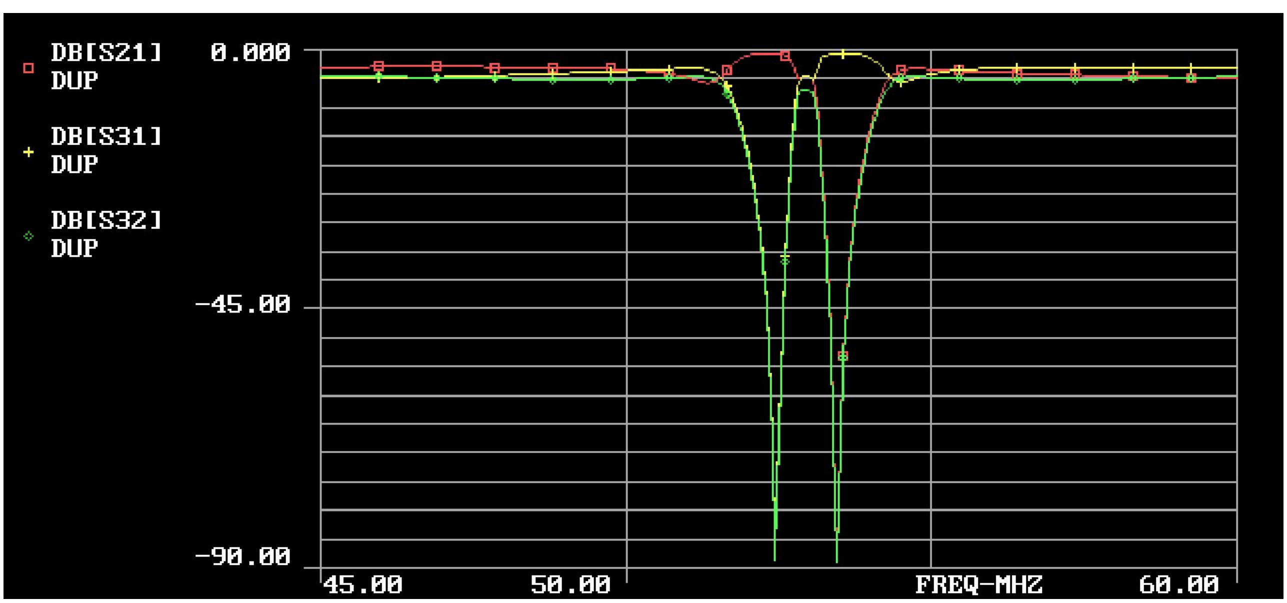


Sweep frequency range 45 MHz to 60 MHz of the 4-stub HR Duplexer encompassing TV CH 2 (54 - 60 MHz). For this sweep the following parameters were measured:

- S21, Red, Receive leg performance measured from Receive port to antenna port.
- S31, Yellow, Tranmit leg performance measured from Transmit port to antenna port.
- S23, Green, Transmit to Receive Isolation Value, mesured from Transmit port to Receive port.

Note the amount of attenuation offered by the Hybrid Ring Duplexer over a broad range of frequencies compared to the Notch duplexer shown below; this is the major feature of this design.

Band Reject Duplexer Performance - Notch configuration (for comparison with HR duplexer)



Sweep frequency range 45 MHz to 60 MHz of a 6-stub Notch Duplexer encompassing TV CH 2 (54 - 60 MHz). For this sweep the following parameters were measured:

- S21, Red, Receive leg performance measured from Receive port to antenna port.
- S31, Yellow, Tranmit leg performance measured from Transmit port to antenna port.
- S23, Green, Transmit to Receive Isolation Value, mesured from Transmit port to Receive port.

It is obvious that the BR (band reject) or Notchs only act to notch basically two frequencies: the transmit and receive frequencies.

-- Duplexer Specs --

Performance:

	Freq	S21	S31	S23	File
with shunt elements	52.000	1.43 dB	93.3 dB	94.3 dB	D6H12203
	53.000	92.4 dB	1.35 dB	93.5 dB	

Duplexer performance can be measured and quantified with three main figures:

1) **Insertion Loss**, measured as an S21 or S31 value at the Receive and Transmit frequencies respectively,
2) **Isolation** (TX to RX Isolation) measured as an S23 value and
3) **Return Loss** measured as S11, S22 and S33 values at the Antenna, Receive and Transmit port respectively.

Insertion Loss

This value is the *measured loss* in the *pass band* of the receiver (or transmitter) leg between the receiver (or transmitter) port and the antenna port at the respective receive (or transmit) frequency. This value represents the small amount of *attenuation* or 'insertion loss' that results when the duplexer is placed in-line between the receiver or transmitter.

The following chart shows the reduction in *transmit power* due to the *Insertion Loss* of the duplexer. A 1 MHz split, 90 dB notch duplexer, properly designed and built, paying particular attention to the key physical parameters that determine the recovery from the 'deep' attenuation notch are capable of achieving insertion loss values of around 1 dB. In the 3rd generation design this is accomplished using microstrip techniques.

	dB	W	dB	W	dB	W	dB	W
dB Insertion								
Loss and	0.7	85	1.1	78	1.5	71	1.9	65
power out	0.8	83	1.2	76	1.6	69	2.0	63
for 100W	0.9	81	1.3	74	1.7	68	2.1	62
transmitter	1.0	79	1.4	72	1.8	66	2.2	60

Isolation

This value is the measured *isolation* between the Transmit port (port 3) and the Receive port (port 2). In S Parameter parlance on this web page, this is the *S23* value.

The 'Isolation' figure reveals the amount of isolation between the transmitter and the receiver. Two such 'values' for isolation exist for every duplexer, one for the receive frequency and one for the transmit frequency.

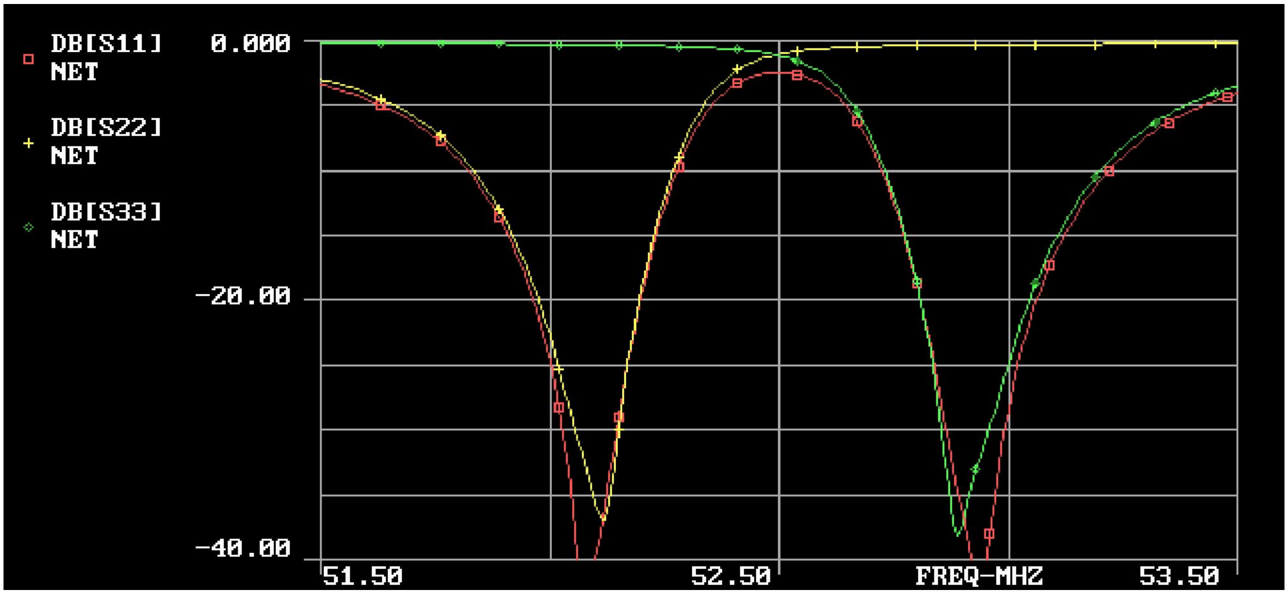
Return Loss (VSWR)

I prefer using the term *return loss* to SWR or VSWR since so very few of us actually measure 'VSWR' directly; usually, we measure *return loss* using a directional coupler (or a directional Watt meter like the famous Bird series) and convert this figure to VSWR using the usual, well-established formulas and via HP's APPCAD utility or the venerable HP VSWR "Reflectometer" slide rule.

To that end, the following close relationships exist between Return Loss and VSWR:

Return Loss	VSWR
14 dB	1.5:1
18 dB	1.3:1
21 dB	1.2:1
26 dB	1.1:1

The *return loss* value, directly related to the VSWR (Voltage Standing Wave Ratio), is a measure of the *match* the duplexer presents to the transmitter, the receiver, and even the antenna. Below is the sweep obtained during modeling of a Heliax duplexer design. Practical experience shows that comparable results can be achieved when building the Heliax duplexer - Return Loss values better than 20 dB translating to a VSWR of around 1.2:1 can be achieved with proper design and tuning.



Sweep frequency range 51.5 MHz to 53.5 MHz of the 4-stub HR Duplexer. For this sweep the following parameters were measured:

- S11, Red, Antenna leg RL performance.
- S22, Yellow, Receive leg RL performance.
- S33, Green, Transmit leg RL performance.

Commercial product - comparison

For comparative purposes, via www.repeater-builder.com/rbtip/duplexerspecs.html we can see what the key performance parameters are for a commercial DB-4032 (an 8-can helical resonator VHF low-band duplexer):

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Type: 8 helical resonators, bandreject
Minimum freq. spacing      0.5 MHz
Insertion loss             2.0 dB
Max. continuous power      150 watts
Tx noise supp. at Rx freq. 80 dB
Rx isolation at Tx freq.   80 dB
VSWR                       1.5:1
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-- History --

The history of duplexer design for Six Meters using Heliax stubs dates back to the late eighties when I began *several years of low-level research* involving the mathematical analysis, simulation and 'bench work' on shorted Heliax stubs; work that finally culminated in a ***proof-of-concept prototype design*** of a notch duplexer in about '**91** which was constructed out of 1 1/4" Heliax.

Duplexer design, website issues, or to have a duplexer built for use on your **VHF low-band commercial** (30 - 50 MHz) repeater or for the **6M Amateur** band **e-mail Jim** (call sign: WB5WPA) at "**jvpoll at dallas -dot- net**" (Be sure to remove the at and -dot- and spaces and replace as required).

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