Ham Tips

from KH6CQ

Number 19

A Strategy for Adding a Digipeater to a VHF Repeater

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I wanted to investigate the practicality of adding digipeater coverage to the same area served by a two meter analog voice repeater. In order to accomplish this as economically as possible, I preferred to use the same feedline and antenna. Doing so would also virtually guarantee that the geographical area covered would be identical.

In order to use the same feedline and antenna, a combiner would be necessary. Combiners are usually expensive items, but if an inexpensive duplexer could be re-purposed to serve as the combiner then this approach would work.

A TX RX Systems model 33-36-04A duplexer was on hand. This is a relatively low-Q duplexer that looks like a mobile flat-pack duplexer on steroids. It is rated at 100 Watts, has a minimum frequency separation of 1.5 MHz., and could be mounted in the duplexer cabinet between the existing cavities.

Figure 1 shows the TX RX Systems cavities mounted in a rack cabinet 6-feet tall. The four cavities at the top are band pass cavities, two for the repeater and two for the digipeater. The four cavities at the bottom are the duplexer for the repeater. The combiner is mounted horizontally in the middle of the rack. Figure 2 is a close-up of the combiner as viewed from the rear of the cabinet.

Refer to the system block diagram shown in Figure 3. The FM voice repeater receives on 147.84 MHz and transmits on 147.24 MHz. The digipeater is a transceiver that can receive and transmit on 144.39 MHz, the nationwide APRS (Automatic Position Reporting System) frequency or one of the digipeater frequencies between 145.01 and 145.11 MHz.

Figure 1 — The two duplexers and band pass cavities mounted in a re-purposed General Electric 19-inch rack cabinet. The front door of the cabinet was removed for this picture.

The Repeater

The repeater in this system is a Motorola MSR 2000. The receiver sensitivity was measured at -125 dBm (0.12 microvolts) for 20 dBq (decibels of quieting). The transmitter has a continuous duty RF power amplifier capable of producing more than 100 Watts output.

The duplexer is a TX RX Systems model 28-37-02A. It consists of four Vari-Notch pass-reject cavities, two in the receive leg and two in the transmit leg. Each cavity is a cylinder 6-5/8 inches diameter and 33 inches tall. Rejection is at least 88 dB per leg and insertion loss is 1.5 dB maximum per leg. These are the four cavities located in the bottom of the rack as seen in Figure 1.

The repeater also uses two TX RX Systems model 11-37-01 band pass cavities. One between the receiver and the duplexer and the other between the transmitter and the duplexer. Each of these cavities is also a 6-5/8 inch diameter cylinder 33 inches tall.

The main purpose of the band pass cavity between the receiver and the duplexer is to provide desense protection from off-channel RF sources. Remember that the duplexer only attenuates the signal at the repeater's transmitter frequency whereas the band pass cavity attenuates all off-channel signals. The fact that it provides about 12 dB more attenuation at the transmitter frequency is a bonus and that increases the total rejection in the receive leg to 110 dB.

The main purpose of the band pass cavity between the transmitter and the duplexer is to provide transmitter noise protection from the wide band white noise generated by the solid-state devices in the power amplifier. A secondary benefit is that it provides 12 dB more rejection at the receiver frequency as well. So with this band pass cavity added to the system, the total rejection in the transmitter leg exceeds 102 dB.

The Digipeater

The digipeater is a Motorola GM300 transceiver programmed for the nationwide APRS frequency (144.39 MHz) as well as the frequencies commonly used for packet radio digipeaters (145.01 through 145.11 MHz). The GM300 is programmed such that it defaults to 145.07 MHz on power-up, then, if desired, any one of the programmed frequencies can be selected by issuing the appropriate DTMF commands.

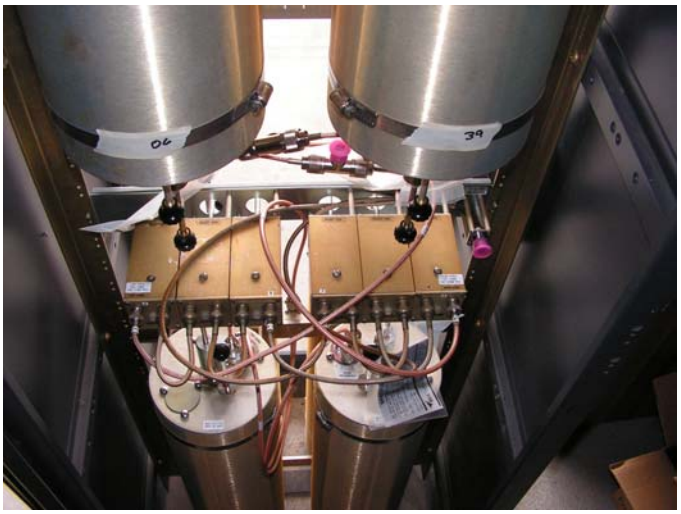

Figure 2 — The second duplexer used as the combiner to add digipeater capability to the system.

Since the frequency spread between 144.39 and 145.11 MHz is wider than a single cavity can pass, a band pass filter consisting of two cavities in parallel was used. One of the cavities is tuned to the APRS frequency and the other is tuned to the geometric center of the digipeater frequencies. Both of these cavities are also TX RX Systems model 11-37-01 band pass cavities. These are two of the four cavities seen mounted upside down at the top of the rack in Figure 1.

The combiner is actually a low-Q duplexer connected in reverse. It is a TX RX Systems model 33-36-04A duplexer designed for applications with a frequency separation of no less than 1.5 MHz. Since the frequency separation in this application is at least 2.13 MHz (147.24 – 145.11 MHz), it was sufficient. It consists of six 2-inch square rectangular resonators, three in each leg. Rejection is at least 70 dB per leg and insertion loss is less than 0.7 dB per leg.

Although the combiner adds a little more loss to the overall system, it is an acceptable trade-off when you take into account the economic advantage of having both the repeater and the digipeater use the same feedline and antenna.

Test Results

Figures 4 through 19 are the actual VNA (vector network analyzer) plots for this system. For these measurements, all open ports were terminated with a 50-ohm load. In each of these plots the yellow trace represents the RF signal passing from one port to another and the blue trace represents the measured return loss.

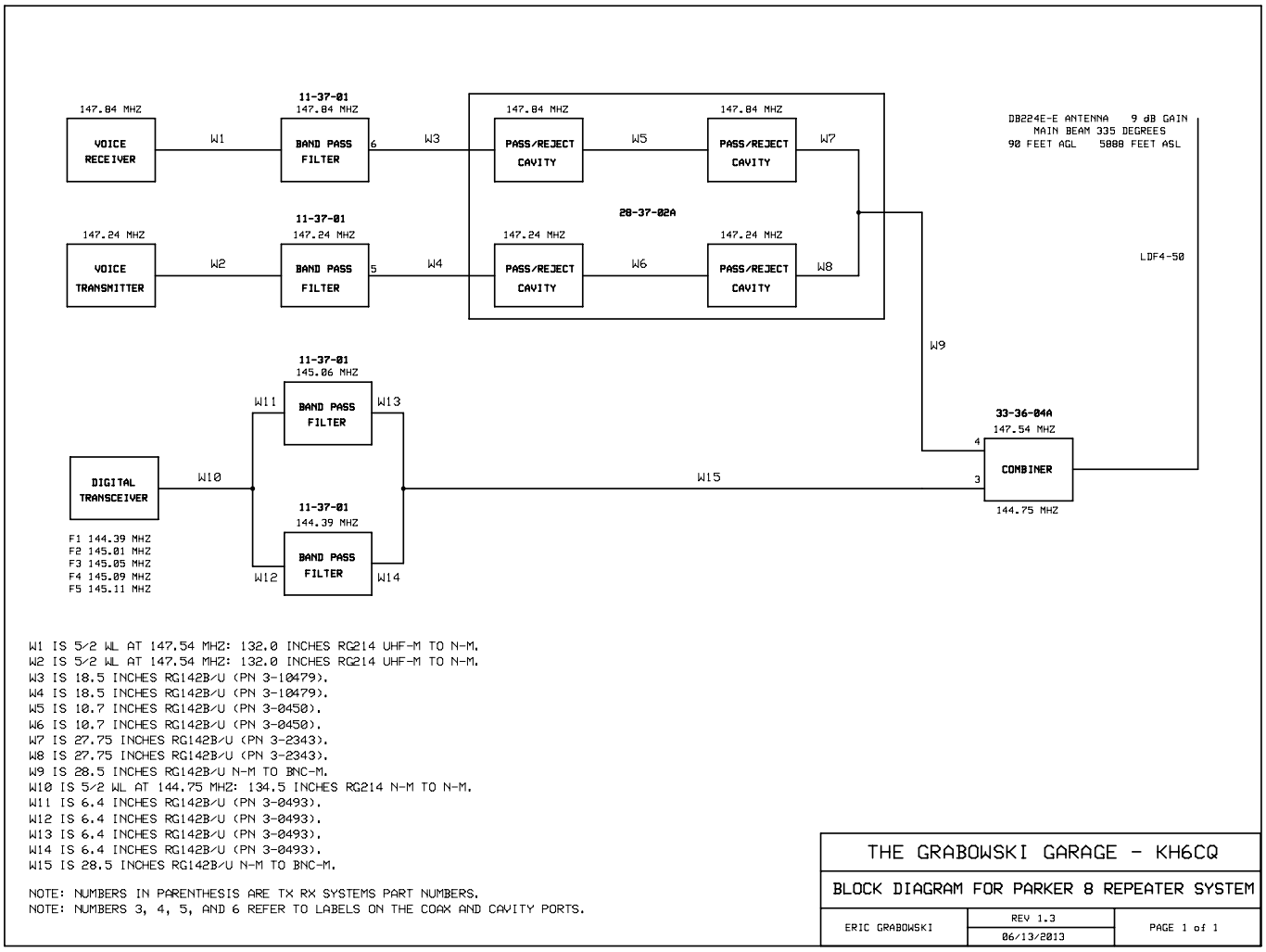

Figure 3 — Block diagram of the entire system showing how the digipeater was added to the voice repeater. A second duplexer connected in reverse serves as a combiner and a two cavity filter network in the digipeater leg was necessary due to the bandwidth requirement. If the digipeater leg were to be configured for either just the APRS frequency or just the digipeater frequencies, then only a single band pass cavity would have been needed.

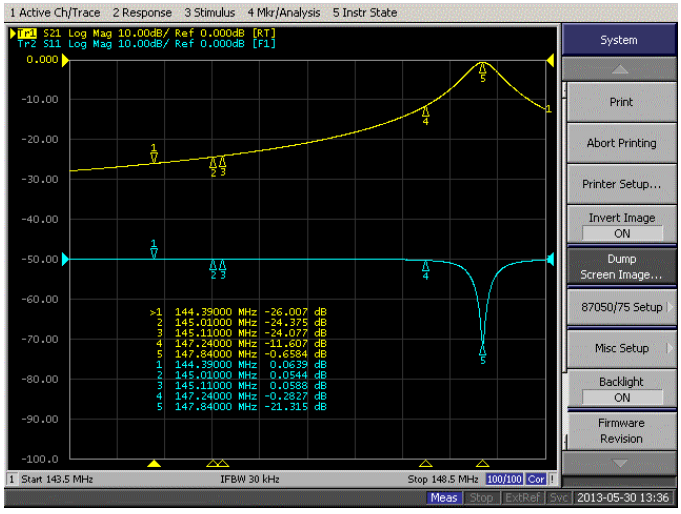

Figure 4 — VNA plot of the band pass cavity connected between the receiver and the duplexer. Attenuation is at least 20 dB for any signal 1.5 MHz or further away from the receiver frequency and nearly 12 dB at the transmitter frequency.

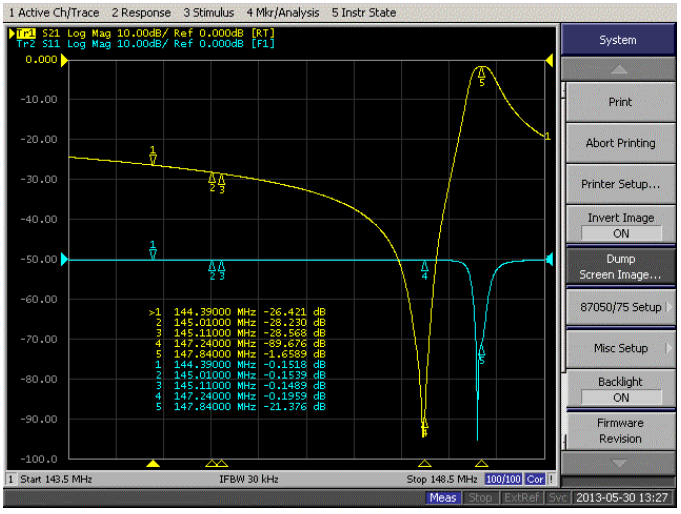

Figure 5 — VNA plot of the response measured from the receiver port to the antenna port of the duplexer.

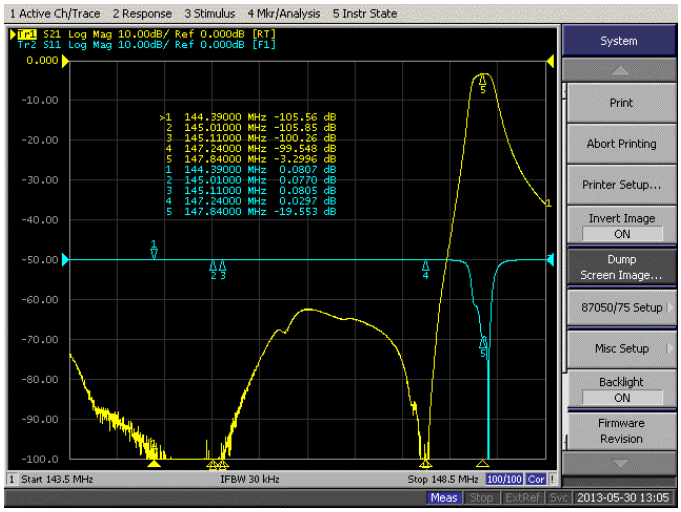

Figure 6 — VNA plot of the response measured from the receiver port to the system antenna port. Addition of the combiner increased the loss in the receive leg by 1.6 dB.

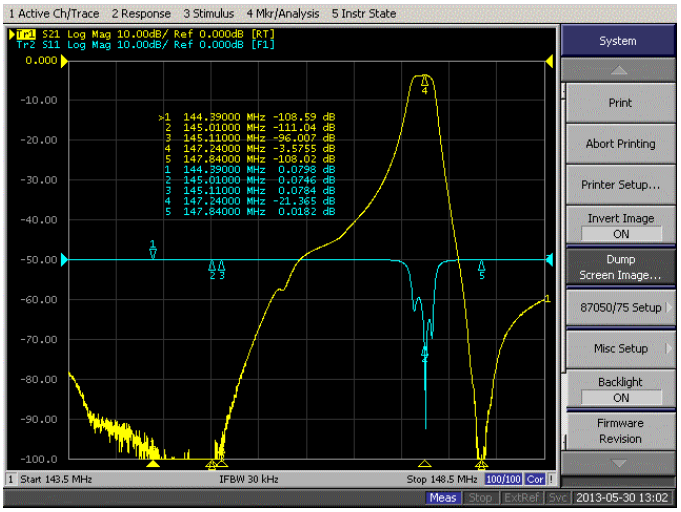

Figure 9 — VNA plot of the response measured from the transmitter port to the system antenna port. Addition of the digipeater increased the loss in the transmit leg by 1.9 dB.

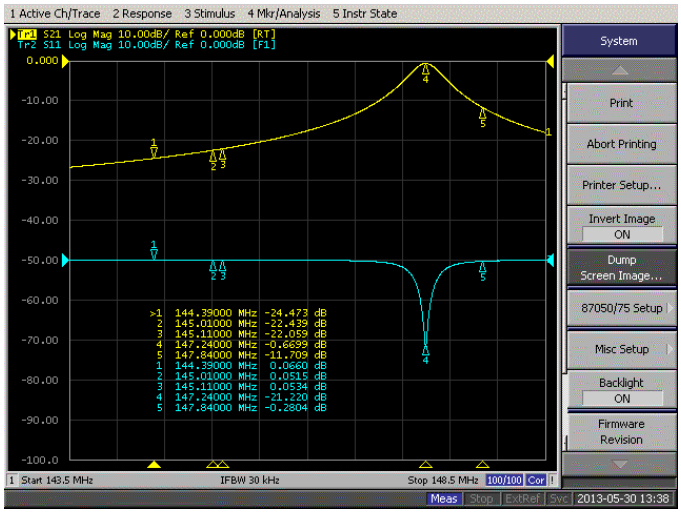

Figure 7 — VNA plot of the band pass cavity connected between the transmitter and the duplexer. Attenuation is at least 20 dB for any signal 1.5 MHz or further away from the transmitter frequency and nearly 12 dB at the receiver frequency.

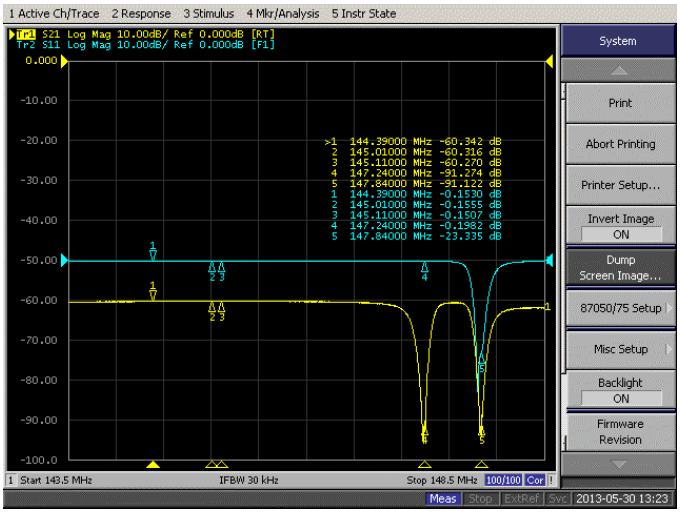

Figure 10 — VNA plot of the response measured from the transmitter port to the receiver port of the duplexer.

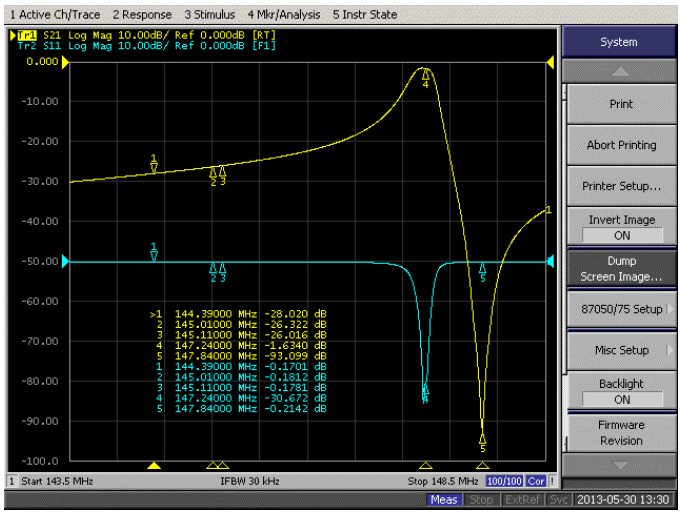

Figure 8 — VNA plot of the response measured from the transmitter port to the antenna port of the duplexer.

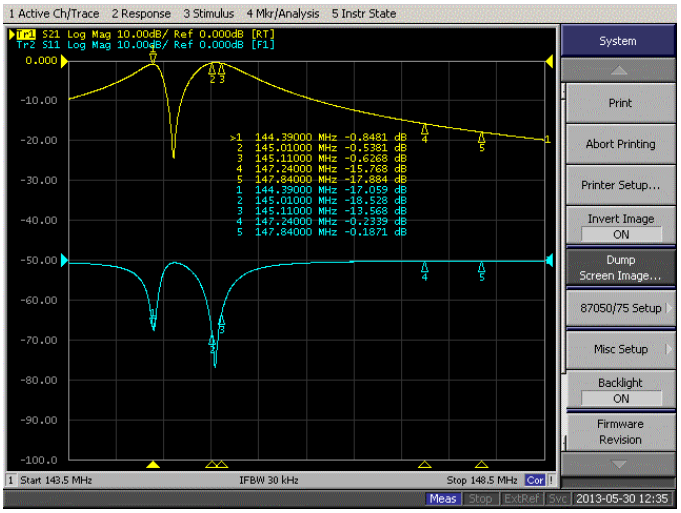

Figure 11 — VNA plot of the response of the band pass filter cavities connected between the digipeater and the combiner. It provides an additional 18 dB of attenuation at the repeater's receive frequency and 16 dB at the repeater's transmitter's frequency.

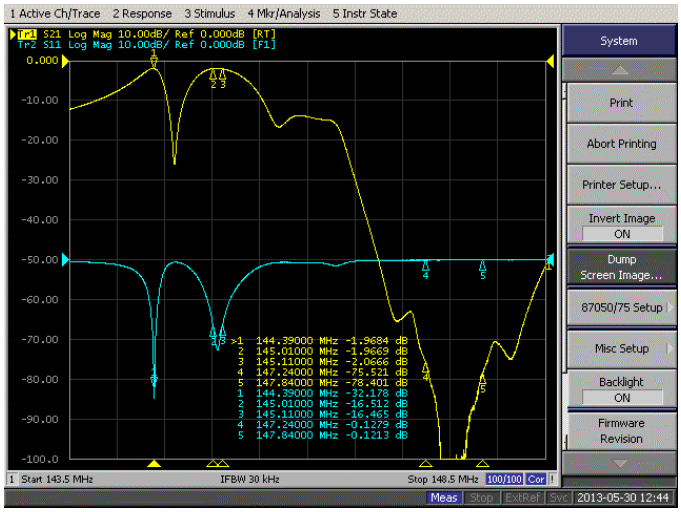

Figure 12 — VNA plot of the response measured from the digipeater band pass filter port to the system antenna port. The insertion loss is less than 2 dB.

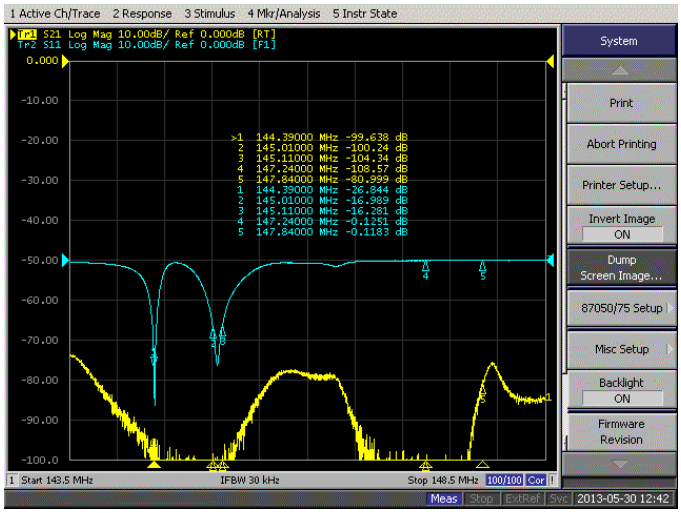

Figure 13 — VNA plot measured from the digipeater band pass port to the receiver port.

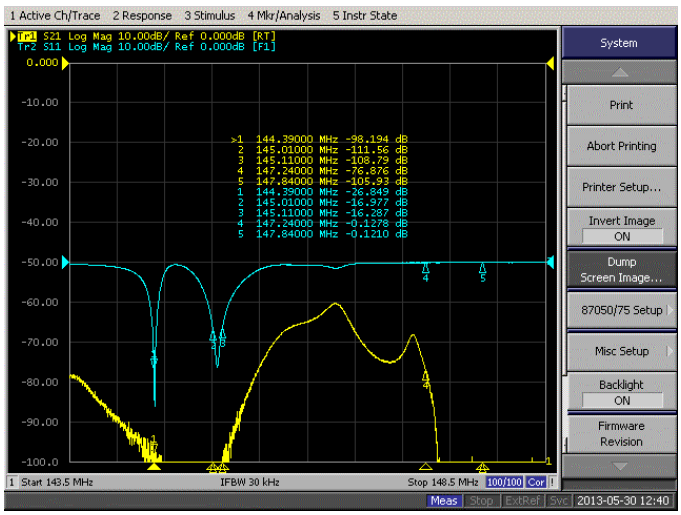

Figure 14 — VNA plot of the response measured from the digipeater band pass filter port to the transmitter port.

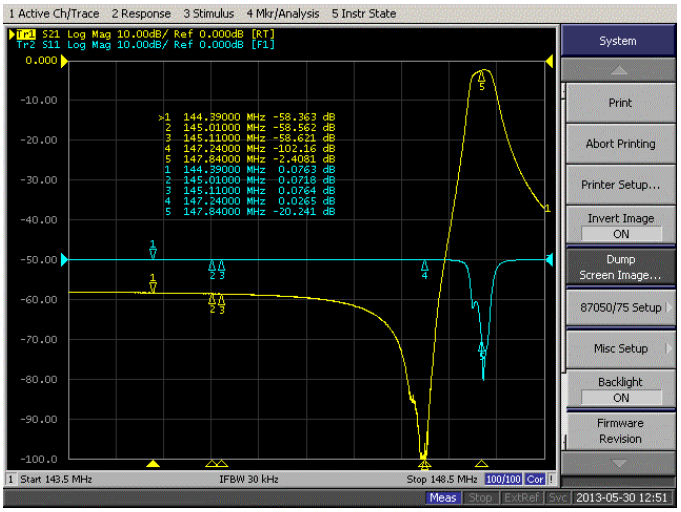

Figure 15 — VNA plot of the response of the combiner showing the pass at the receiver frequency.

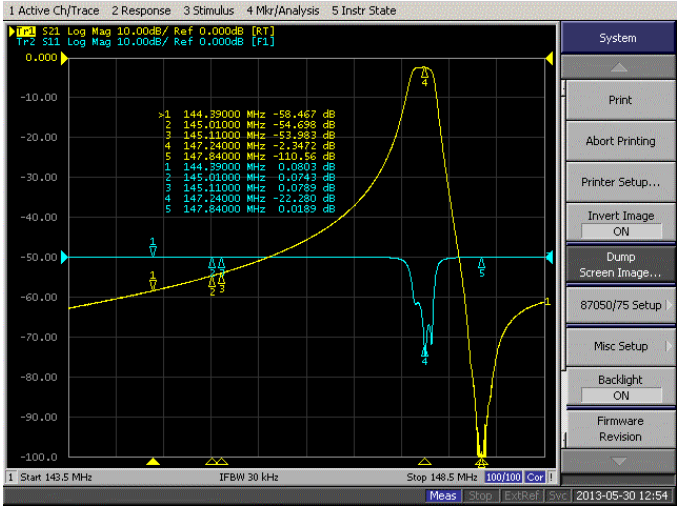

Figure 16 — VNA plot of the response of the combiner showing the pass at the transmitter frequency.

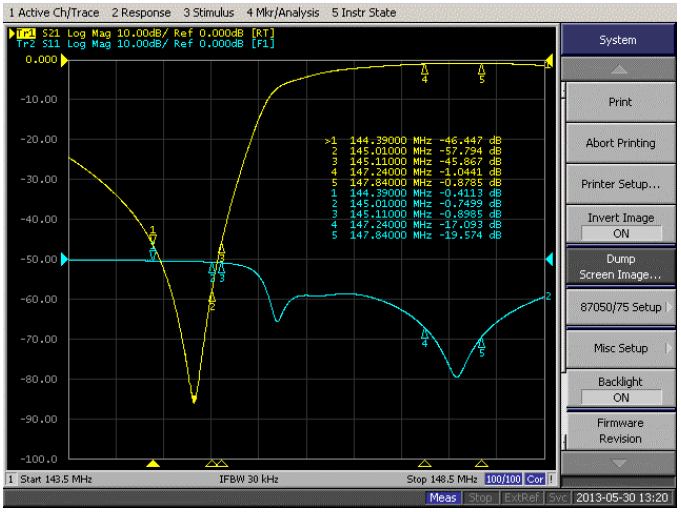

Figure 17 — VNA plot of the response of the combiner on the repeater leg.

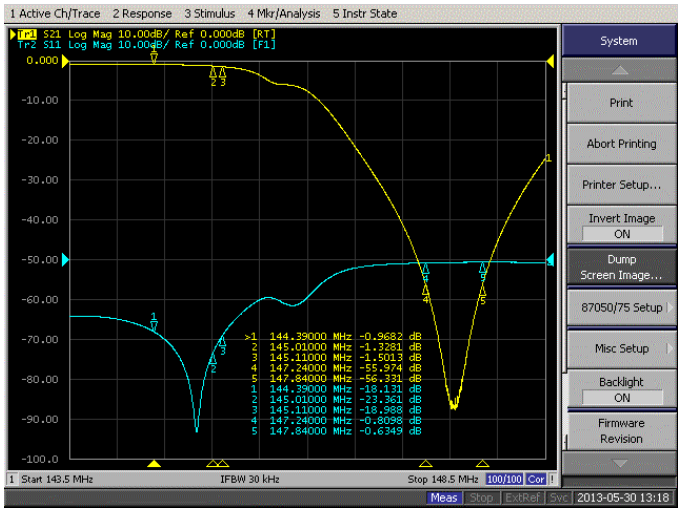

Figure 18 — VNA plot of the response of the combiner on the digipeater leg.

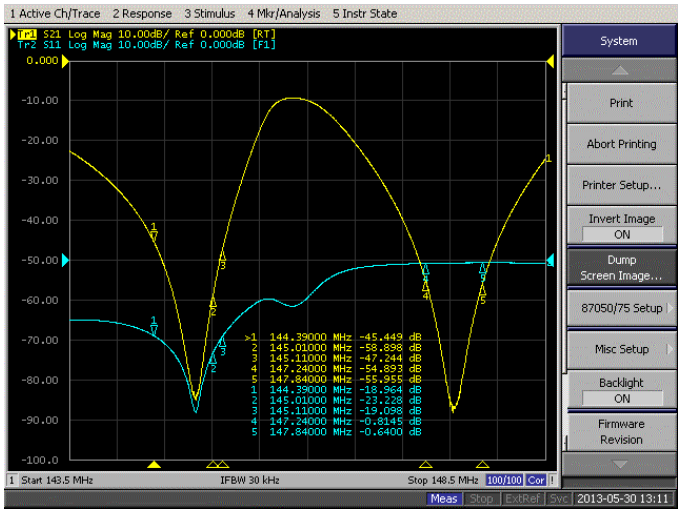

Figure 19 — VNA plot of the response of the combiner measured between the digipeater and the repeater ports. The frequency for the digipeater notch was a compromise to provide the most reasonable amount of attenuation at all of the low-end frequencies.

Summary

This Ham Tip described a strategy for adding a digipeater to an existing VHF analog voice repeater. It is an economical way to provide packet radio coverage to the same geographical area as the repeater without the additional expense for another antenna and feedline. The trade-off is only a slight additional loss in the repeater leg.

This strategy was successful because the spread between the repeater and digipeater frequencies in this application was large enough so that an inexpensive low-Q duplexer was able to provide satisfactory performance as the combiner.

Typical flat-pack duplexers have a minimum transmit-receive split between 1.5 and 3.0 MHz. That means if the voice repeater is in the 147 MHz part of the band, you have a good chance of using one successfully. If, on the other hand, the voice repeater is in the 145 or 146 MHz repeater sub-bands, a more robust duplexer may be needed for the combiner or this technique may not be feasible at all.

Acknowledgements

Projects such as this one are built on the work of others who have gone before and shared their experiences with the rest of the amateur radio community. In particular, I would like to thank the following authors for their articles and assistance:

Dwayne Kincaid, WD8OYG, for the article “Adding an APRS Digipeater to VHF Repeater” (www.aprs.org/txt/digiduplexing.pdf)

Private emails from Field Services Project Manager Tony DelGobbo of TX RX systems, a division of Bird Technologies. Tony provided a lot of technical information, advice, and performed several VNA sweeps of potential configurations before this design was finalized.

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