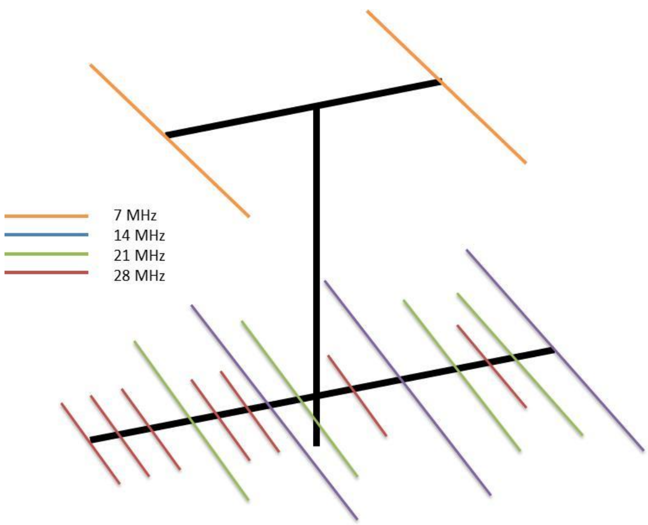
by KØZR, Jeff Crawford November, 2014

SO2R Requirements

Essentially there are two requirements for every SO2R installation. The first and most important criterion is protection from damage for each receiver, followed by sufficient reduction of unwanted transmissions into the adjacent receiver affording it the best opportunity for small signal reception.

In my installation the first item above is foremost in importance. I use a Force12 C31XR tribander at 72 feet, and by virtue of the fact that all elements are on the same boom, a high degree of undesirable coupling exists for the SO2R operation. This has been worrisome to the extent that before trying SO2R operation with the tribander, I wanted to do some calculations and measurements. This short paper outlines my measurements and findings. If you are entirely new to SO2R this will provide some insight for you.

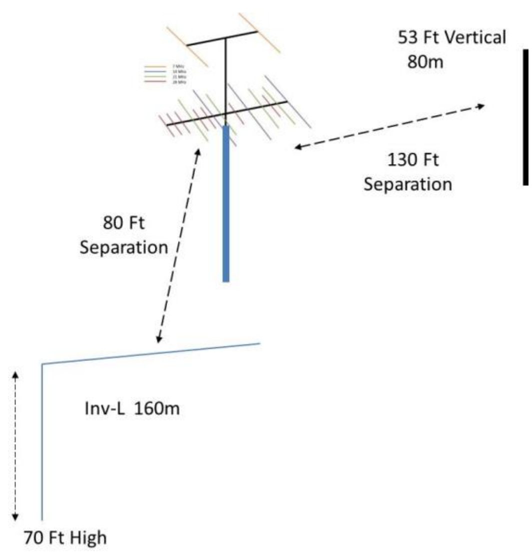
Antennas at KØZR



To the left is a figure showing the antenna configuration on the 72 foot crankup tower. The top 7 MHz antenna is a Cushcraft XM240. The bottom antenna is the 14-element, Force12 C31XR which covers 14, 21, and 28 MHz. They are separated 8 feet.

I believe most C31XR installations use a single coax feed. Obviously this is not an option for SO2R unless one uses a 2 KW triplexer to evolve one coax per frequency band. In my case I modified the C31XR, following most of the Force12 instructions, for three separate feed lines. The largest differences in my modification were some shortening of the 10m radiator and replacement of the four-turn 15m hairpin coil with a 2-turn coil. I believe the largest influence driving these small changes was due to the presence of the XM240.

I found when the tower was cranked down to 23 feet with the XM240 at 31 feet, the VSWR was properly positioned in the CW portion of the 7 MHz band, but upon extending the tower to its full height, the resonant frequency moved higher in the band. I lengthened the XM240 radiator by ½ " on each end and the reflector by ¾" on each end. Anywhere above 60 feet elevation the XM240 displays a 1.1:1 resonance near 7.04 MHz.



The rest of the KØZR antenna story is shown to the right. The inv-L path is "in front of" the C31XR as one looks northeast from the tower. Probably not "desirable", but antennas in the front yard are not either, thus the orientation. The 53 foot vertical is ground-mounted with 90 radials.

Isolation Matrix

My first endeavor was to measure the degree of coupling or isolation between each antenna and the others. This is the "first line of defense" for the other receiver. The manner in which this was done is the following. I used a Rigol spectrum analyzer with a built-in tracking generator to, in essence, measure S_{21} between each possible pair of antennas. In the interest of time and what I deemed suitable accuracy, I considered the measurement floor to be near – 70 dBm. I had the tracking generator set for an output level of 0 dBm.

		Antenna Coupling Matrix			
		TX Band			
RX Band	**160**	**80**	**40**	**20**	**15**	**10**
160	X	-60	-60	-60	-60	-60
80	-60	X	-57	-59	-51.5	-62
40	-60	-51	X	-48.8	-47.5	-50.4
20	-60	-60.6	-53.7	X	-43.9	-36.1
15	-60	-71.3	-15.6	-40	X	-26.1
10	-60	-66.2	-49.8	-45.5	-48.7	X

Table I

S_{21} Between the Various Antennas

Additional Rejection

I had the fortune to come across a 300 ft roll of RG11 coax for which I had to pay only about $18. Wanting to afford the greatest receiver immunity for simultaneous transmissions possible, I have also incorporated a number of stubs on each antenna. With the help of the Rigol spectrum analyzer, the open and shorted stubs were easily tuned for greatest effectiveness. A good reference for this construction is from K2TR. In my case the velocity factor was 0.825 rather than 0.66 as used throughout the cited reference. The performance plots of my additional stubs are shown in the Appendix.

It does speed things along if you have reasonable accuracy in determining the velocity factor of the cable. In my case I measured the physical length of cable , then using the Array Solutions AIM-4170, "tweaked" the velocity factor until the "distance to the fault" (i.e. the open or short at the end of the cable) was what I had measured for the length of the cable. A few iterations and I arrived at 0.825.

			TX Band			
RX Band	160	80	40	20	15	10
160	X					
80		X	-23.6	-20	-17.6	-15.5
40		-25	X	-26.3	-30.4	-23.6
20			-24.2	X	-20.9	-21.5
15				-25	X	-22.2
10			-25.3	-30	-22.8	X

Table II

Stubs in use at KØZR

Bandpass Filters for Each Receiver

Each receiver needs additional protection afforded by band-dedicated filters, especially if one is using high power, as is my situation. Originally I was on a course to build my own filters, but the difficulty in obtaining reasonable cost, high voltage capacitors for the project diminished my interest. Therefore, in use at KØZR is a pair of Array Solutions BandPasser II filters, one on each receiver. The worst case results in the CW portion of each band are shown in Table III below.

	Filter Performance					
			TX Band			
RX Band	**160**	**80**	**40**	**20**	**15**	**10**
160	X	-42	-60	-60	-55	-55
80	-44	X	-45	-55	-55	-60
40	-60	-55	X	-51	-55	-55
20	-55	-55	-60	X	-48	-48
15	-50	-55	-53	-47	X	-41
10	-45	-40	-35	-57	-48	X
	* 70 dB ~ beyond ability to measure					

Table III

Filter Performance by Band

Composite Results

Within Microsoft Excel I coupled all the aforementioned results into one table which is duplicated below in Table IV. My desire is to have 120 dB isolation between any transmitted signal and that which appears in the other receiver. While I did not achieve this across all six bands, the cumulative attenuation is impressive and considered generally more than adequate for my needs.

	Compilation of Results					
			TX Ant			
RX Ant	**160**	**80**	**40**	**20**	**15**	**10**
160	X	-102	-120	-120	-115	-115
80	-104	X	-125.56	-134	-124.1	-137.5
40	-120	-131	X	-126.1	-132.9	-129
20	-115	-115.6	-137.9	X	-112.8	-105.6
15	-110	-126.3	-90.6	-112	X	-89.3
10	-105	-106.2	-110.1	-132.5	-119.5	X

Table IV
S_{21} Between Antenna Pairs

Green: > 120 dB Isolation
Yellow: 100 - 120 dB Isolation
Red: < 100 dB Isolation

The "problem areas" are between 15m-40m and 15m-10m. Generally speaking, I believe it unlikely that I will be operating 40 m simultaneously with 15 m so that may be a non-problem. That is not the case, however, between 10m and 15m, which I envision ping-ponging between each when conditions are favorable. It is good that these bands are not harmonically related which would exacerbate this problem.

At a 1600 watt level (a little calculation safety), and a cable loss of 0.75 dB, an attenuation of 120 dB results in a power level at the adjacent receiver of -58.5 dBm. Still a strong signal, but hopefully one a reasonably good receiver can deal with. Table V starts at 1600 watts and considers the isolations just determined to arrive at the signal level in the adjacent receiver.

	Power Level Into Adjacent Receiver for 1600 W Input					
		TX Band				
RX Band	**160**	**80**	**40**	**20**	**15**	**10**
160	X	-40.99	-58.99	-58.99	-53.99	-53.99
80	-42.99	X	-64.55	-72.99	-63.09	-76.49
40	-58.99	-69.99	X	-65.09	-71.89	-67.99
20	-53.99	-54.59	-76.89	X	-51.79	-44.59
15	-48.99	-65.29	-29.59	-50.99	X	-28.29
10	-43.99	-45.19	-49.09	-71.49	-58.49	X

Table V

Anticipated Signal Levels from 2nd Transmitter

Input Levels Into Adjacent Receiver

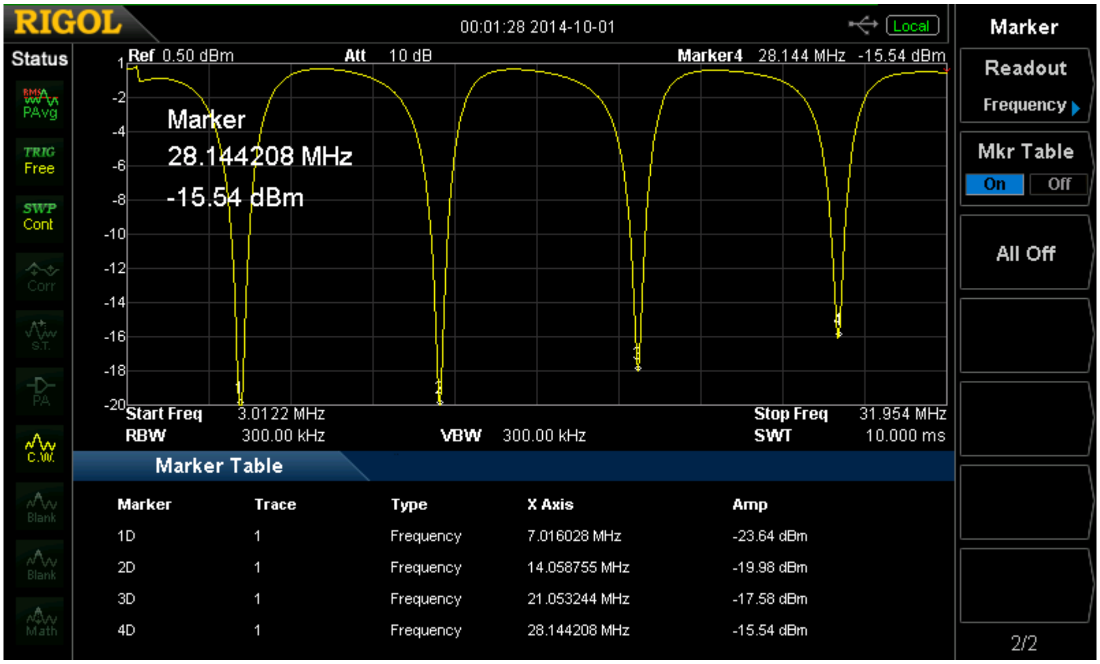
Reference

K2TR Coax Stub Filters at n6ws.com/files/stubs.pdf

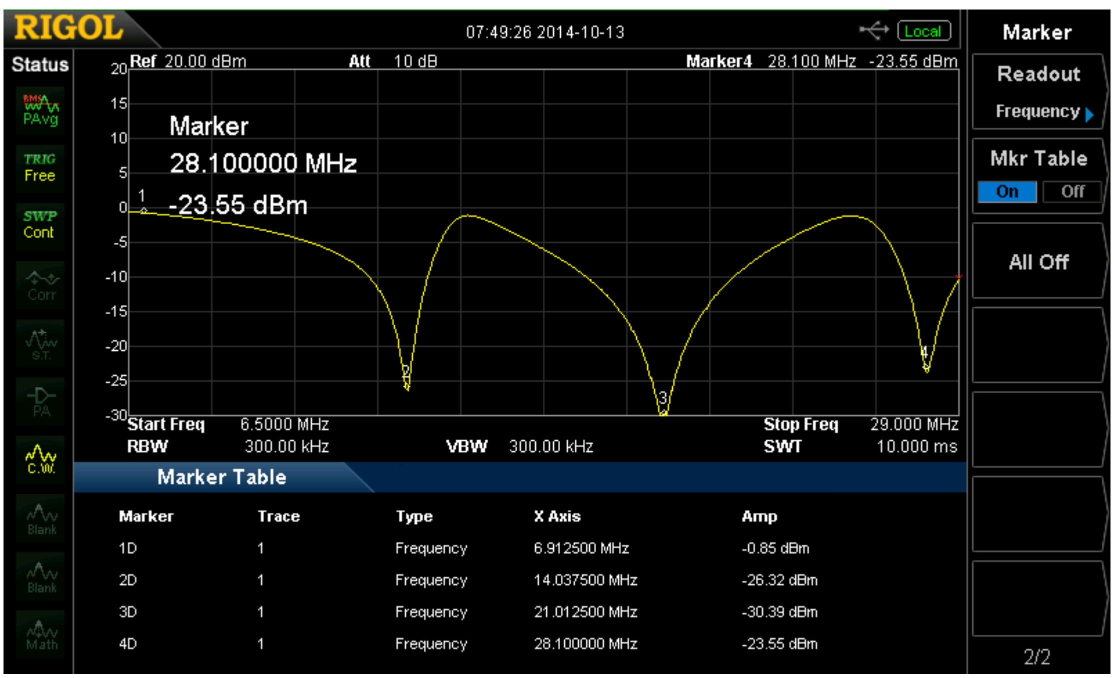
Appendix

		TX Power	**1346.23**	**Watts**		
Isolation	Pow Into Receiver		dBm			
30	1.346232227		31.2912			
40	0.134623223		21.2912		TX Power-	1600
50	0.013462322		11.2912		0.75 dB Lo	1346.23
60	0.001346232		1.2912			
70	0.000134623		-8.7088		in dBm	61.2912
80	1.34623E-05		-18.7088			
90	1.34623E-06		-28.7088			
100	1.34623E-07		-38.7088			
110	1.34623E-08		-48.7088			
120	1.34623E-09		-58.7088			

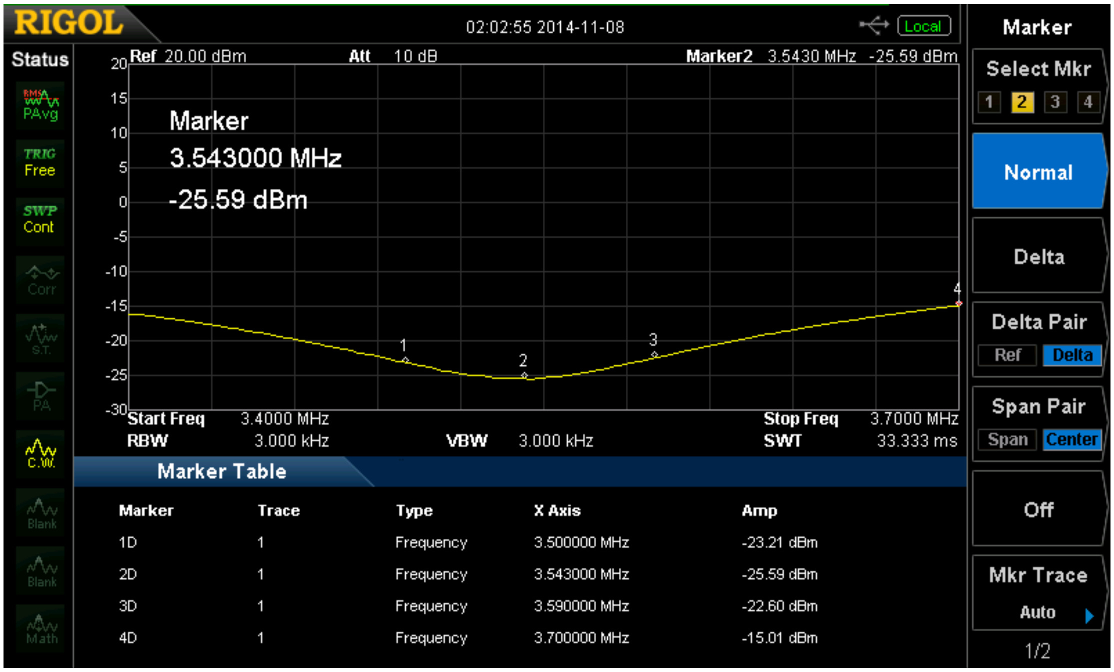
Individual Stub Performance



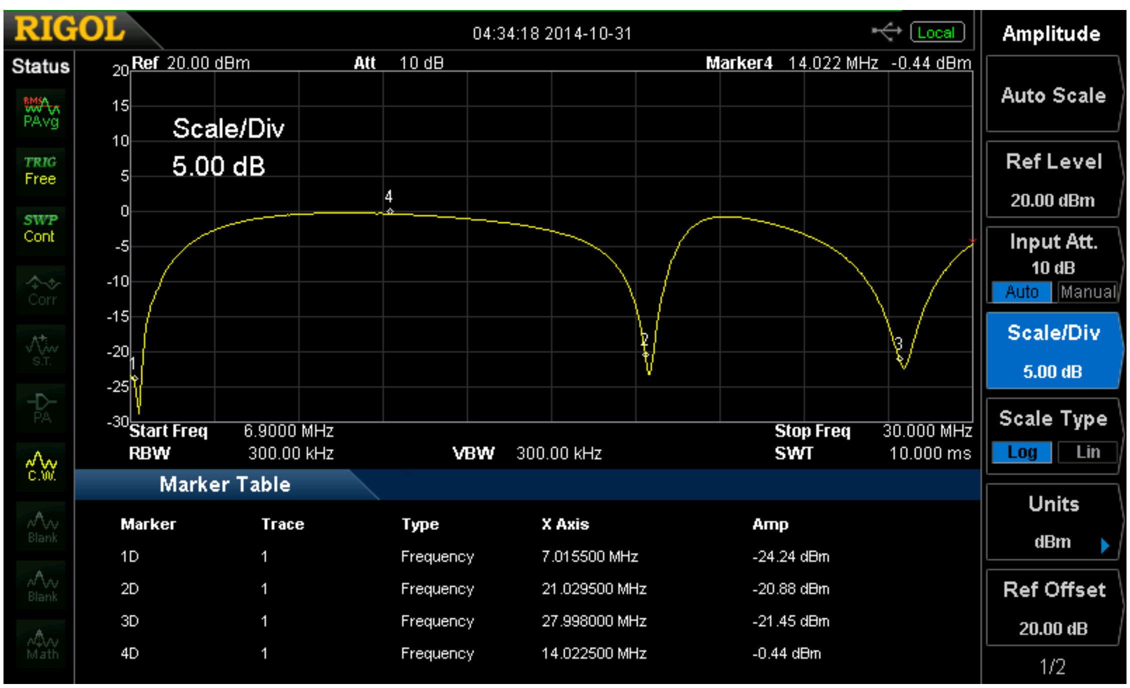
Used on 80m Vertical Antenna – Rejects 40, 20, 15, and 10m



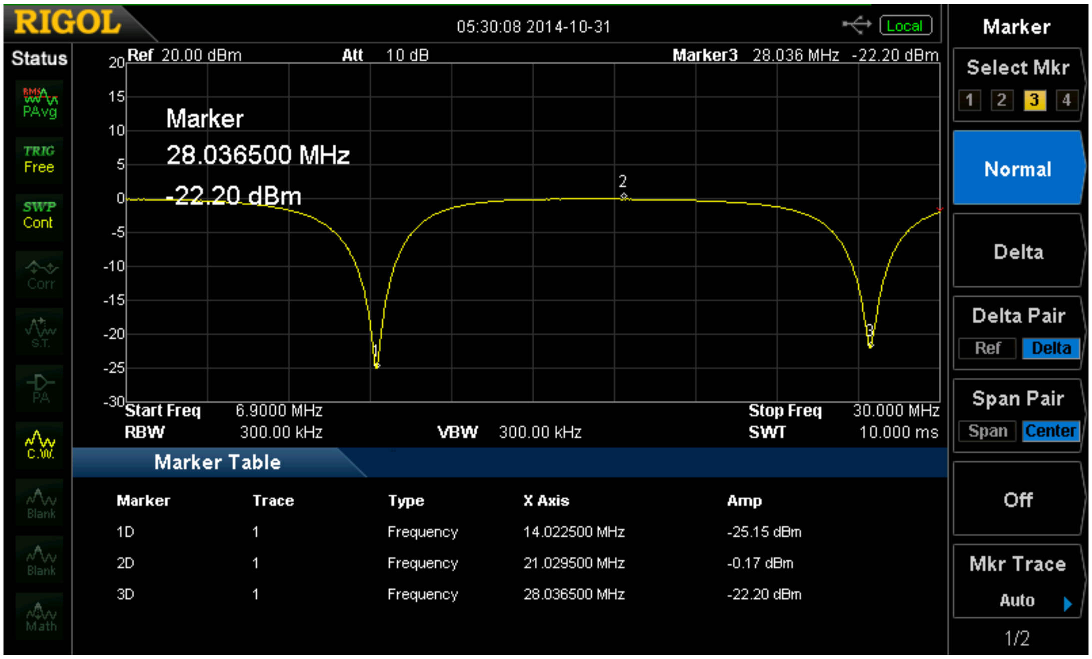
One Pair of Stubs Used on 40 m Antenna – Rejects 20, 15, and 10m



An Additional Stub Placed on the 40m Antenna to Reject 80m

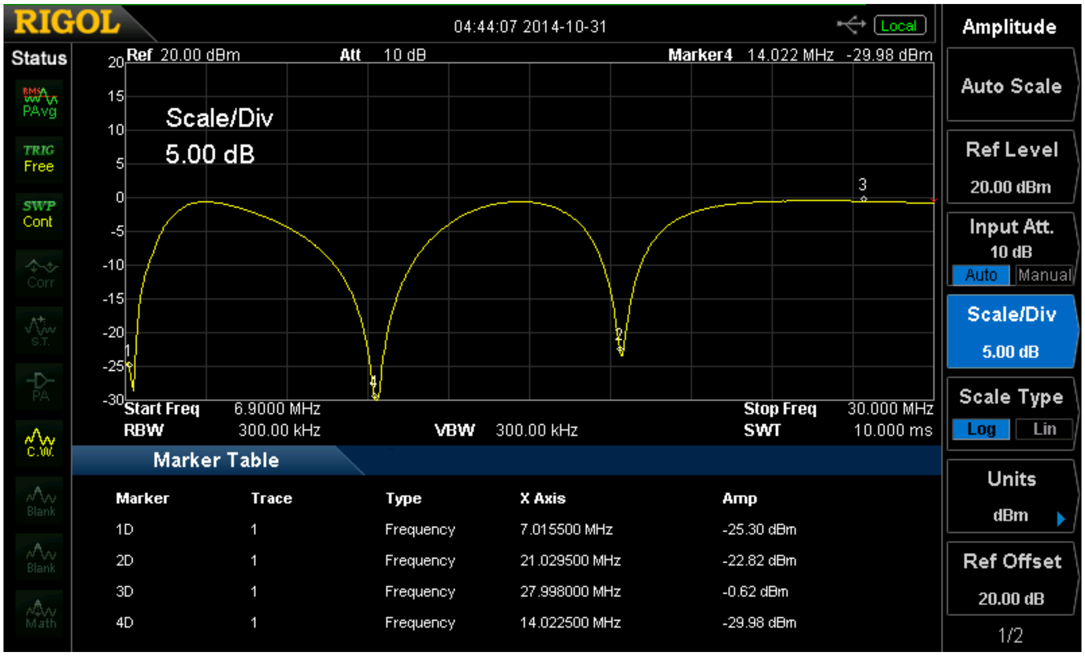


Used on 20m Antenna – Rejects 40, 15 and 10m



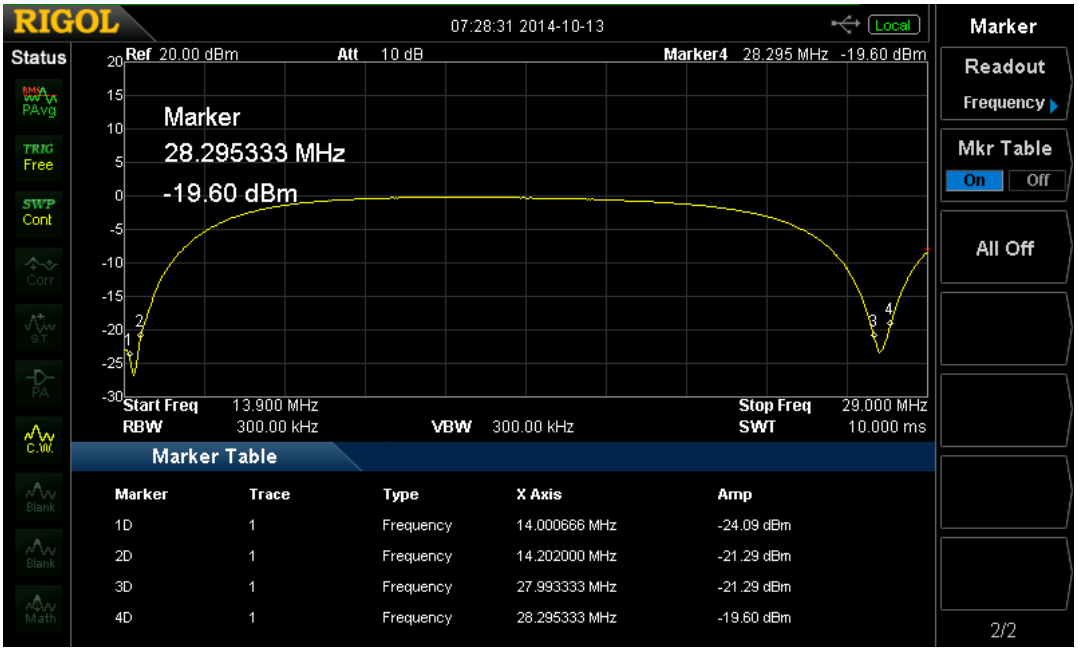
Use on 15 m – Rejects 20 and 10m

Additional Stub on 15m Antenna to Reject 40m Signals

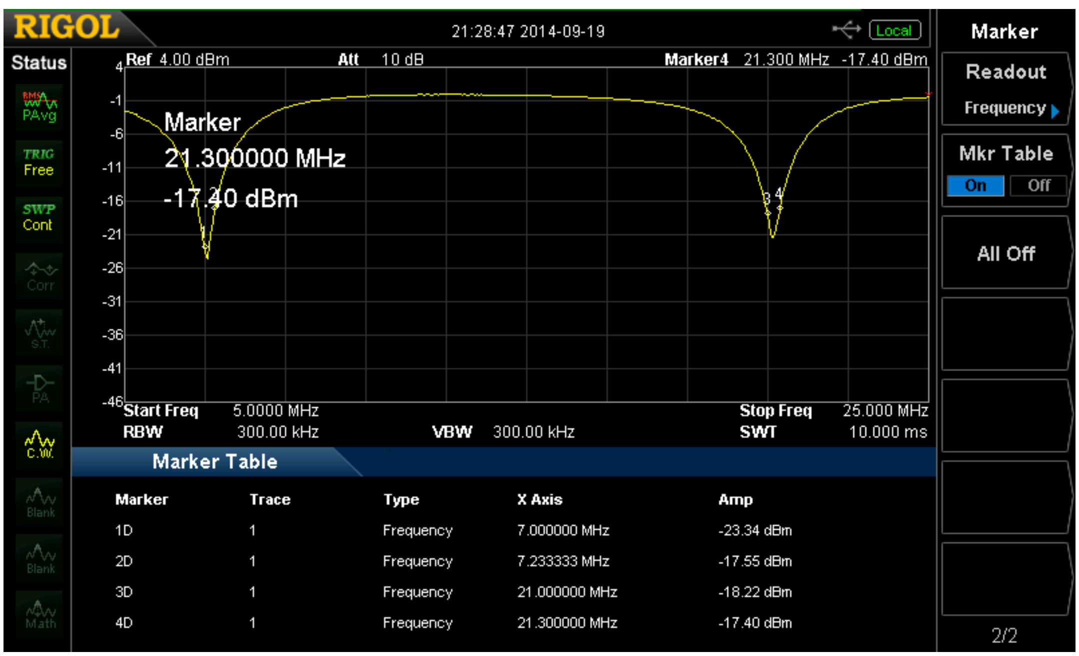


Marker	Trace	Type	X Axis	Amp
1D	1	Frequency	7.015500 MHz	-25.30 dBm
2D	1	Frequency	21.029500 MHz	-22.82 dBm
3D	1	Frequency	27.998000 MHz	-0.62 dBm
4D	1	Frequency	14.022500 MHz	-29.98 dBm

Use on 10 m – Rejects 40, 20, and 15m



Close-up of 15m Stub Performance



Close-up of 20m Stub Performance