Beacon Blaster 6

A simultaneous six-channel FST4W-120 beacon system

User's Guide and Specifications

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IMPORTANT!

The BB-6 (Beacon Blaster 6) is an experimental Amateur Radio device, and has not been submitted for formal FCC certification. When operated under normal conditions the BB-6 should comply with U.S.A. FCC requirements for harmonic and other spurious content, but the responsibility for proper operation is assumed by the operator.

At least in some cases, the BB-6 USB port will not work when directly connected to a USB 3.0 port. However, it will work with an intermediate USB hub (even a USB3 hub.) In any case, I recommend using a USB hub with a fairly short cable to the BB-6. The USB connection is required for initial BB-6 configuration, but is not necessary after configuration.

For more information, contact us at https://turnislandsystems.com/

Changes to This Document

V1.1: Correction to the “**Schedule**” command.

Introducing the Beacon Blaster 6

What it Does

- Transmits FST4W-120 beacon signals on six HF ham bands, simultaneously
- Precise frequency accuracy and stability using external 10 MHz reference clock
- One Watt output power on each channel, any ham band from 160 through 10 meters
- Flexible per-channel transmit scheduling, optional CW identification
- Can run with or without USB-connected computer

Why

- Propagation research
- General beacon station

Dimensions

The Beacon Blaster 6 is housed in a 1RU (Rack Unit) enclosure:

19” wide x 1.75” high x 10.5” deep

It weighs slightly under five pounds.

Connections

All ports are on the BB-6 front panel. They are:

- Channels 1-6 Output - Six SMA jacks
- GPS Antenna – SMA jack
- GPS Auxiliary (antenna connection splitter output) – SMA jack
- Reference Clock Input (10 MHz) – SMA jack
- USB - type B
- Power - 5.5 x 2.1mm barrel jack

Power

The Beacon Blaster 6 requires a 9-16V DC power source, and uses a 5.5 x 2.1mm barrel jack power connector, positive pin and negative sleeve.

Typical Power Consumption, all ports transmitting into filters with 50 Ohm load:

Vin	I_{DC}	Watts
9 V	1.54 A	13.9 W
12 V	1.14 A	13.7 W
16 V	0.85 A	13.6 W

A regular 9V or 12V “wall wart” DC power supply is usually adequate, but any source of clean DC power can be used. Supply switching noise is typically not a problem, as this input voltage is connected to a secondary internal regulator and distribution system with distributed supply-noise filtering.

GPS Antenna and GPS AUX

The BB-6 requires a connection to an external GPS antenna, either directly, or through a GPS antenna splitter. The BB-6 will provide “phantom” power to the typical active GPS antenna.

The BB-6 GPS antenna port feeds an internal passive splitter, one output feeding the internal GPS receiver, and the other connected to the GPS AUX jack. This AUX jack can be used to feed an external GPSDO. This internal splitter has a 6dB loss, so low input levels may not provide enough signal for BB-6 or GPSDO operation. If an external splitter is used, it should probably be one with amplification.

10 MHz Reference Clock

An accurate and stable 10 MHz reference clock is required by the BB-6, with an input level (sine or square-wave) between -10dBm and +20 dBm. A GPS Disciplined Oscillator is typically used. The REF CLK port provides a 50 Ohm termination.

If no reference clock is provided, the BB-6 will optionally still function, but at a greatly-reduced accuracy and stability. See the “CLK” command for configuration details.

USB connection (for configuration and monitoring)

The BB-6 USB port provides:

- A serial port connection used for monitoring and temporary configuration changes
- A “flash drive” style file access to the “commands.txt” configuration file
- A “flash drive” style file access used when updating the BB-6 program

The USB connection is required for initial BB-6 configuration, but is not necessary after configuration. In the absence of DC power the USB port will power the BB-6 control board,

but not the channel-output amplifiers, allowing for configuration, etc. but not transmit operation.

At least in some cases, the BB-6 USB port will not work when directly connected to a USB 3.0 port. However, it will work with an intermediate USB hub (even a USB3 hub.) In any case, I recommend using a USB hub with a fairly short cable to the BB-6.

Channels 1-6 Output

These SMA jacks are the outputs of the six BB-6 channels. They provide a 1W square-wave signal, which *must* be passed through an appropriate filter before being connected to the antenna. While these outputs can be operated unloaded (no connection) they should not drive an impedance below 25 Ohms. Keeping the SWR at 2:1 or better is recommended. The amplifiers do have over-current protection, and will shut down when over-loaded.

Output Filters or Filter/Combiner

Four-Band Filter/Combiner

Illustration 1: Four-Band Filter/Combiner

The 4-Band Filter/Combiner has connections for 80, 40, 20, and 10 meters, for connection to a multiband antenna. The maximum power level is 1W per port, and the attenuation is typically 0.5 dB. Port-to-port isolation is 20 dB or better.

Six-Band Filter/Combiner

(In development, not yet available)
The 6-Band Filter/Combiner will have connections for 80, 40, 30, 20, 15, and 10 meters, but at a somewhat higher loss (about 1dB) than the 4-Port unit.

Seven-Band Filter/Combiner

(Available by special order)

The 7-Band Filter/Combiner adds a 60 meter port, and is capable of higher power and lower loss than the smaller combiners. But this level of performance requires custom-wound toroid inductors (14 of them), which makes this a much more expensive option than the smaller band-count combiners.

Illustration 2: Seven-Band Filter/Combiner

Single-Band Filters

(In development, not yet available)

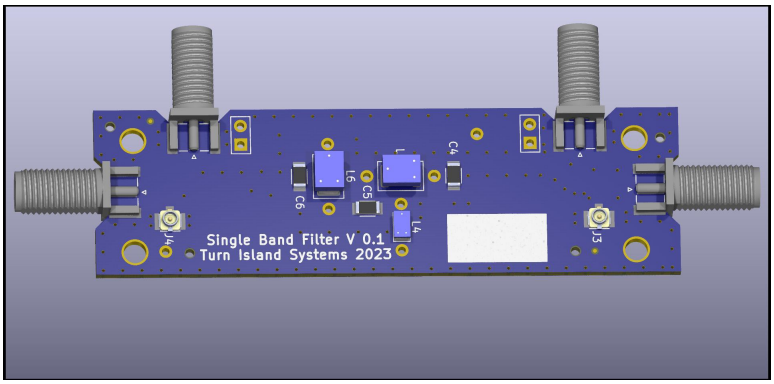


Illustration 3: Single-Band Filter

The Single-Band filter has the option of in-line or right-angle connectors.

Configuring the BB-6, Step by Step

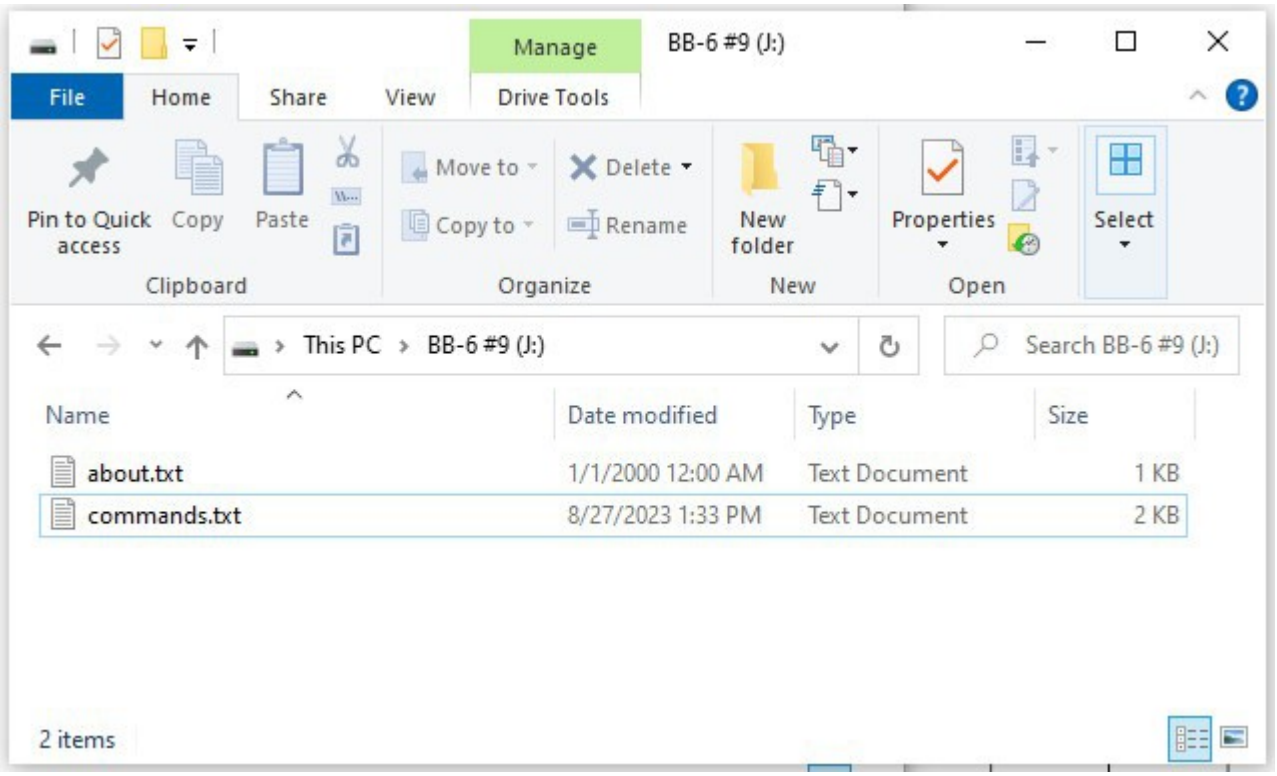
Status LED:

When USB or Power is connected to the BB-6 the Status LED will blink to show the current state:

- 1 blink : Waiting for frame start
- 2 blinks : Waiting for frame start, amplifier power fault
- 1 off-blink : Transmitting
- 2 off-blinks : Transmitting, amplifier power fault
- 3 blinks : GPS Fault
- 4 blinks : RefClk Fault
- continuous blink : identify, or undefined fault

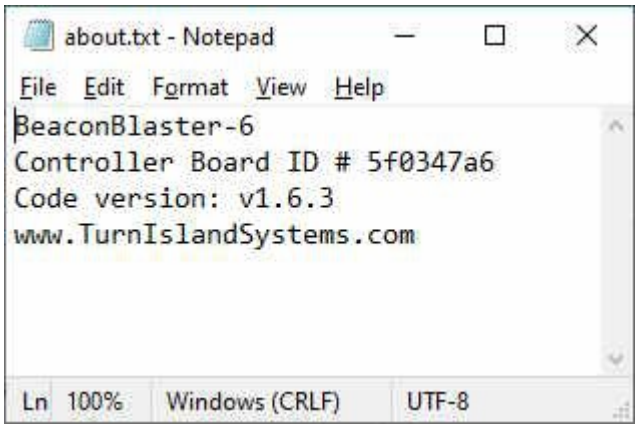
Connect the USB Cable

You can also connect the power at this point, but this is not necessary. A “Flash Drive” file window will probably pop up. If not, search for the drive (it will probably be named “BB-6 #(serial #”, but this name can be changed at will.)



There will be at least two files shown:

- "`about.txt`" – This shows the 32-bit Controller Board ID, and the current program version.



- "`commands.txt`" – This is the configuration file for the BB-6, and is read at power-up, or when the command "config r" (read the configuration file) is entered on the command line.

Edit the `commands.txt` file as appropriate for your station. You can also type these commands in via the serial port command line interface, but any changes will not be saved. Once the configuration file is as you want it, either type "CONFIG R" (read the config file), or power off the BB-6 (disconnect the USB cable **and** switch off or unplug the power. When the BB-6 restarts it will read the updated `commands.txt` file

*Typical Configuration File [**commands.txt**]*

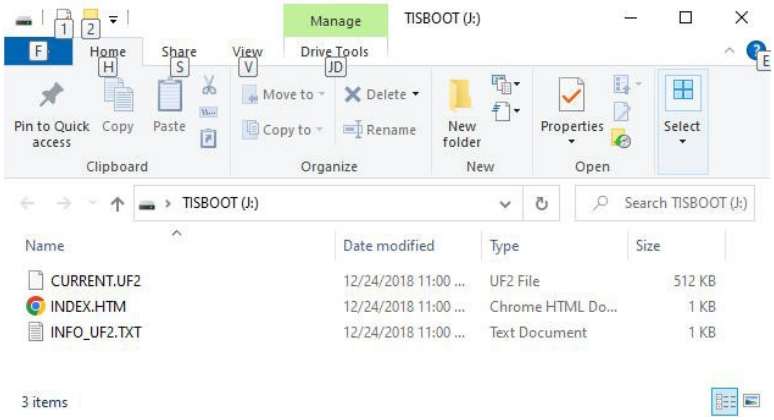
```
# callsign, power level, (grid is optional)
# If grid is not entered it will be set using the GPS position
ID N0CALL 30 CM88

# This sets channel 1 to the 80 meter WSPR/FST4W band,
# with an equivalent 1420 Hz "tone 0" frequency
chan 1 80 20
# and channels 2-6 on 40, 30, 20, 15, and 10 meters
chan 2 40 20
chan 3 30 20
chan 4 20 20
chan 5 15 20
chan 6 10 20

# setting all channels for continuous transmission, no morse ID
sched 1 1 1
sched 2 1 1
sched 3 1 1
sched 4 1 1
sched 5 1 1
sched 6 1 1

# At the start of each frame, serial port report of basic per-channel status
report 1
```

Note: There is a limit to the size of the commands.txt file – approximately 1000 characters maximum – and any text beyond this will be ignored. This will be fixed, but it's a good idea to make sure that all commands are properly interpreted. Using the command-line "**`config r`**" command will let you see the commands as they are processed. Remove comments if necessary.

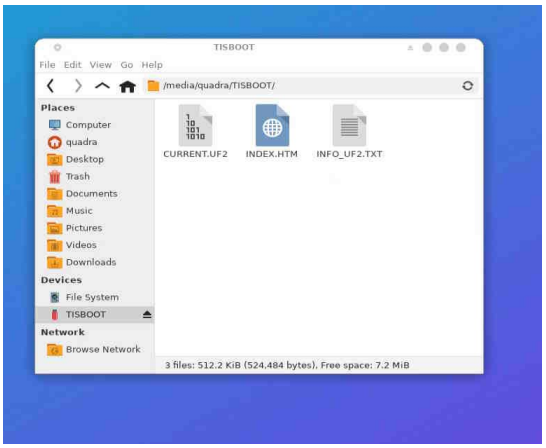
Updating the BB-6 Program

You can install a different version of the BB-6 program, found at
https://turnislandsystems.com/downloads/

On the command line, enter "**`LOADNEW 1`**", and the BB-6 will halt normal operations and enter the program update mode. A flash drive file will pop up (or you may have to search for it):



On linux, the drive might look like this:



Just drag and drop the new ".UF2" file onto the drive window. The BB-6 will install the new program and reboot. Your configuration settings will not be changed.

Commands

Command List

To see the full list of available commands, type “?” and “??” in the command line.

These will change as the software evolves, but the basics will retain compatibility.

> ?

BB-6 v1.6.3

ID [callsign] [power] ([grid]) : Input call/power(/grid) for FST4W Message (will use GPS position if grid not specified)

MORSE [morse ID message]

Channel [1/2/3/4/5/6] [band (160/80/60/40/30/20/17/15/12/10/6)] ([offset (0-20 Hz)])

SCHEDuler [channel] [slot] [repeat] ([Morse ID interval])

RUn : enable all channels

STOP : disable all channels

ENAble [n] : Enable channel [n]

DISable [n] : Disable channel [n]

REPort [1/0] : enable/disable sequence reports

MAN [command] : command information

?? : Show advanced commands

> ??

About : Serial #, etc.
CONFIG [R/D] : read config file ([filename]) / DIR

Status [0-5]: Status messages

GPS : GPS status

BLINK [0/1] Turn off/on front-panel fast blink

TEST [0/1/2/3/R/X] : Test Tone 0, 1, 2, 3, Random FSK, Disable Test

FIXed [chan] : Set fixed freq mode

FILter [0/1] : GFSK Filter off/on

GPSSET [timeout in seconds] : Loss of GPS timeout

CLK [1/0] Require 10 MHz Reference for BeaconBlaster transmit?

LOADNEW [1]: Stop program and show update drive

WARNING: Changing output or PLL dividers is for testing only and will alter transmit frequencies and FSK shifts

FREQ [chan pll a b c (t0 t1 t2 t3)]: custom frequency settings

PLL [reset] or [0-3 a b c] : set pll 0-3 divider values

enter "PLL R" to return PLL frequencies to the defaults

Command Help

To see the full list help for available commands (in essentially random order), type "**`man *`**" on the command line.

> man *

Config [R/D] (filename)

"R" (optional filename): reads the configuration file. The default filename is m"D" : displays all files on the internal BeaconBlaster drive. Please note that filenames must not include spaces!

Report [1/0]

"1" enables the per-timeslot report, showing which channels are transmitting.

ID [callsign] ([power in dBm]) ([gridsquare])

These will be used to generate the beacon message.

NOTE: Early software versions require that the POWER level be set here.

Callsign must be a non-compound type

Power value defaults to "30" to indicate the BeaconBlaster 1W transmit power.

If grid square is not entered then one will be generated using the GPS coordinates.

Channel [channel] [band] ([offset in Hz])

This sets the transmit frequency for a channel.

channel : 1-6

band : 160/80/40/30/20/17/15/12/10 meters, or "X" to disable.

offset : 0-20 Hz from the bottom of the bandplan. Default is zero, which if probably not
t he best frequency to use.

Filter [1/0]

"1" enables the Gaussian FSK filter (default)

"0" disbles the Gaussian FSK filter (for testing)

PLL

This is an experimental feature.

Test [0/1/2/R/X]

Test will cause all channels to transmit various test signals:

"0, 1, 2, 3" : Send FSK tone #0-3

"R" : Send a random FSK pattern.

"X" : Exit test mode.

Run enables all channels

Stop disables all channels

Enable [channel] enables a channel.

Disable [channel] disbles a channel.

Schedule [channel] [transmit slot] [sequence length] ([morse ID interval])
channel: 1-6
transmit slot : transmit on slot #
sequence length : repeat every # timeslots
morse ID interval : send morse ID rather than beacon every # transmissions.

Examples:
Sched 1 1 1 : channel 1, transmit every timeslot.
Sched 1 1 2 : channel 1, transmit every two timeslots, starting with timeslot 1.
Sched 6 3 3 : channel 6, transmit every three timeslots, starting with timeslot 3.
Sched 4 1 1 5 : channel 4, transmit every timeslot, sending morse message every five transmissions.

Status [#]

This shows various status messages.

0: Current time and per-channel state.

1: Amplifier supply Voltage, Reference Clock status, and GPS status

2: Channel frequencies and schedule

3: Channel mode

4: Overrun (internal diagnostic, not critical)

5: Clock Generator divider values.

6: Fault conditions

7: Show callsign, power, grid

GPSset [timeout]

This sets the GPS timeout in seconds before "loss of GPS" is declaerd.

A value of "0" allows the BeaconBlaster to run without a valid GPS input

(in this case frame alignment may be significantly off

GPS [R/N/X] (for testing)

"R" sends the GPS "RMC" sentences to the serial port.

"N" sends all GPS sentences to the serial port.

"X" stops the sending of GPS sentences.

Morse [message string]

The string can include any legal Morse code characters, length limited to 63 characters.

This message will be transmitted in place of a normal beacon message as configured with the "Schedule" command.

Vamp : shows amplifier voltage (5V nominal)

Vamp [mV): sets amplifier voltage fault value in millivolts (zero to disable fault indication).

About

This shows the BeaconBlaster hardware serial# and firmware version.

Loadnew [1] (include the "1")

This will halt the BeaconBlaster for the loading of a new program

Copy the new "UF2" into the TISBOOT directory, and the BeaconBlaster will restart

Blink [1/0]

If you have multiple BeaconBlasters BLINK is used to help identify which one you are connected to.

"1" starts the STATUS LED blink, and "0" stops it.
All other BeaconBlaster operations are unaffected.
Status blink states:
1 blink : Waiting for frame start
2 blinks : Waiting for frame start, amplifier power fault
1 off-blink : Transmitting
2 off-blinks : Transmitting, amplifier power fault
3 blinks : GPS Fault
4 blinks : RefClk Fault
continuous blink : identify, or undefined fault

Clk [1/0] : Require 10 MHz Reference for BeaconBlaster transmit?

1: Require (default).

0: Don't Require (for testing only).

Man [command name]
shows help for a command
Man *
shows help for a all commands

Technical Details

Transmit Spectrum

Each of the six BB-6 channels have a Digital One-Watt Class-D amplifier (DOW), which generates a square-wave output. These outputs can be set to operate between 1 MHz and 50 MHz, and will require an external filter to attenuate the strong harmonic content of the square-wave:

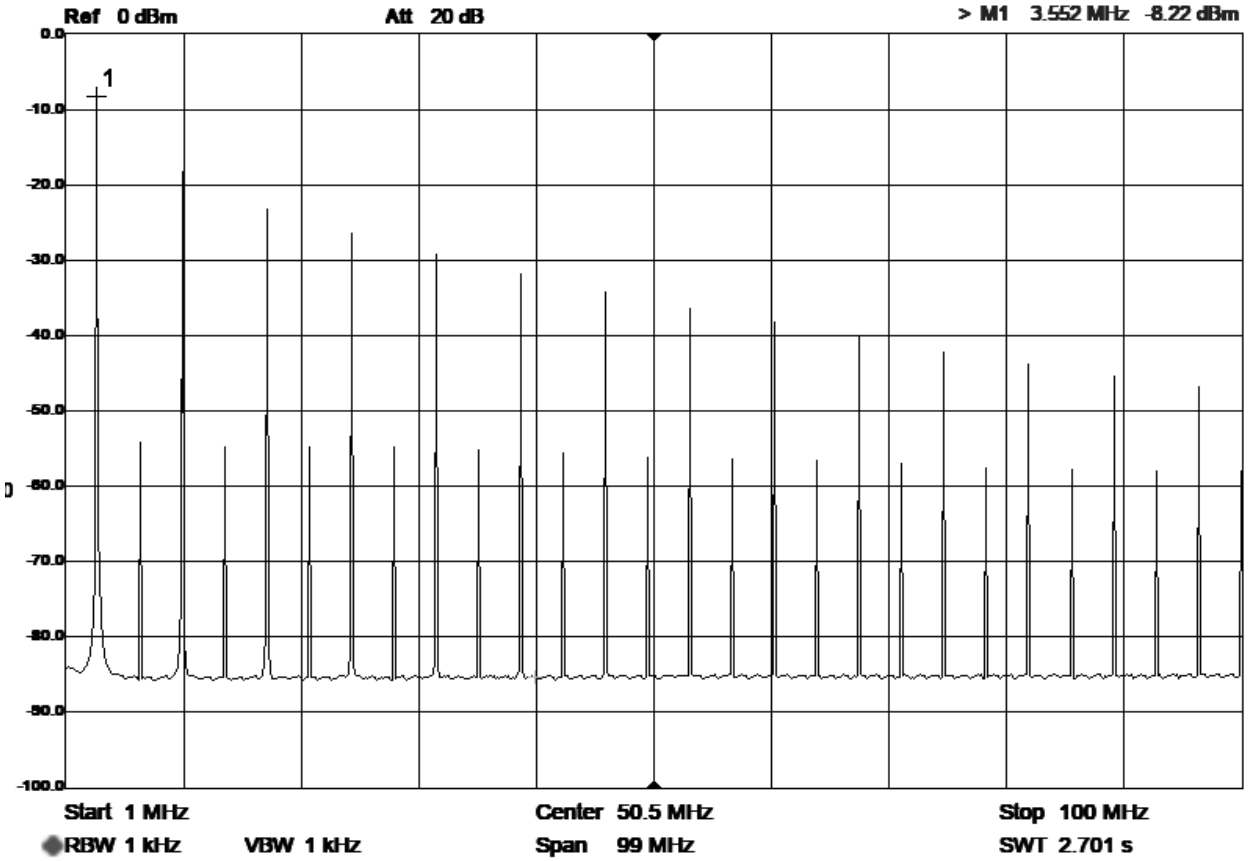


Illustration 4: 80 Meters Without Filter

This is the output of a DOW Amplifier transmitting a 3.5 MHz signal.

The Filter/Combiners are designed to attenuate these harmonics, and the resulting output signal will have harmonic content better than -50 dBc (decibels relative to the carrier.)

80 Meters:

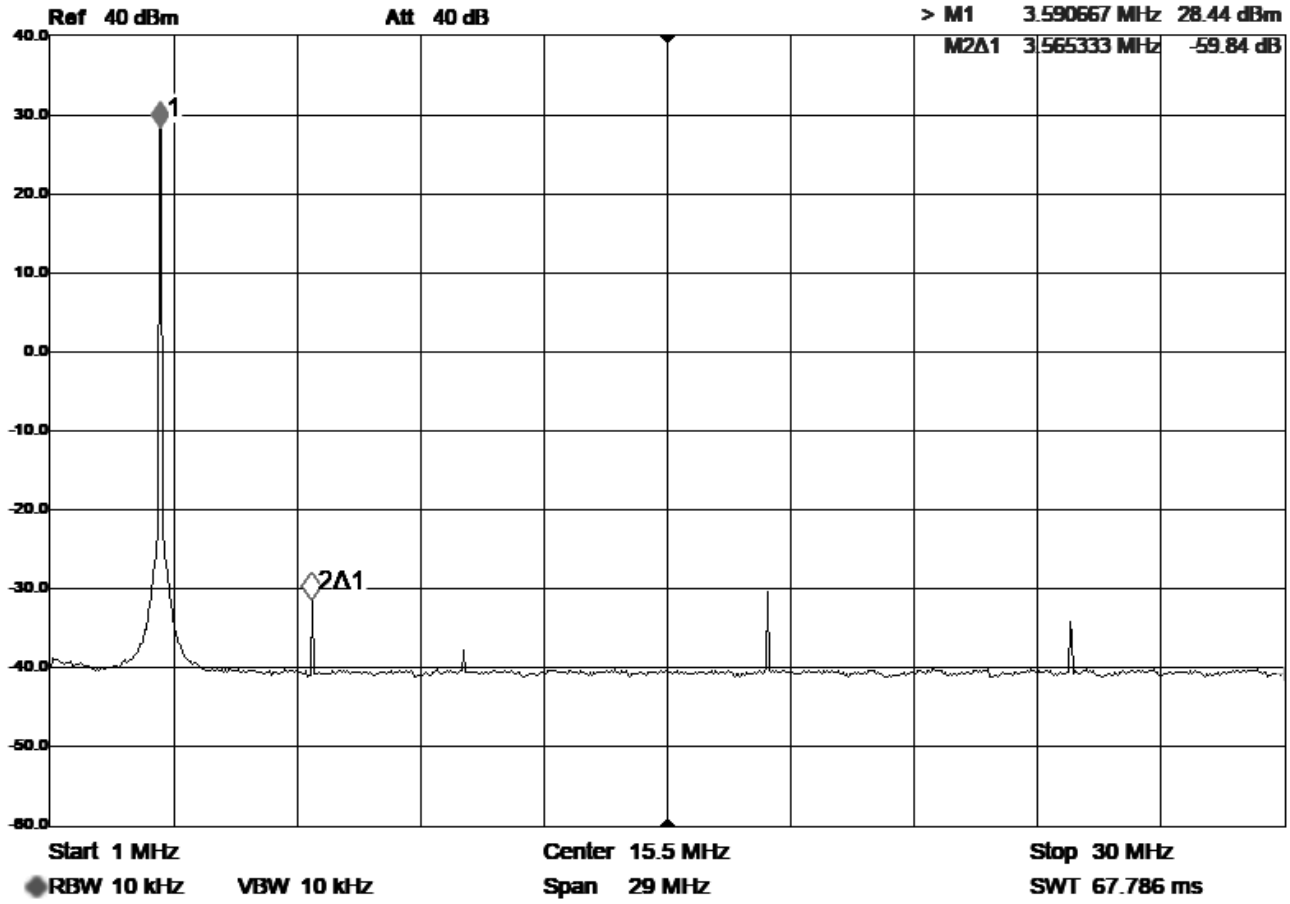


Illustration 5: 80 Meters With Four-Band Filter/Combiner

But the transmit signals will also have close-in spurious content, due to the synthesis method being used. These are better than -40 dBc.

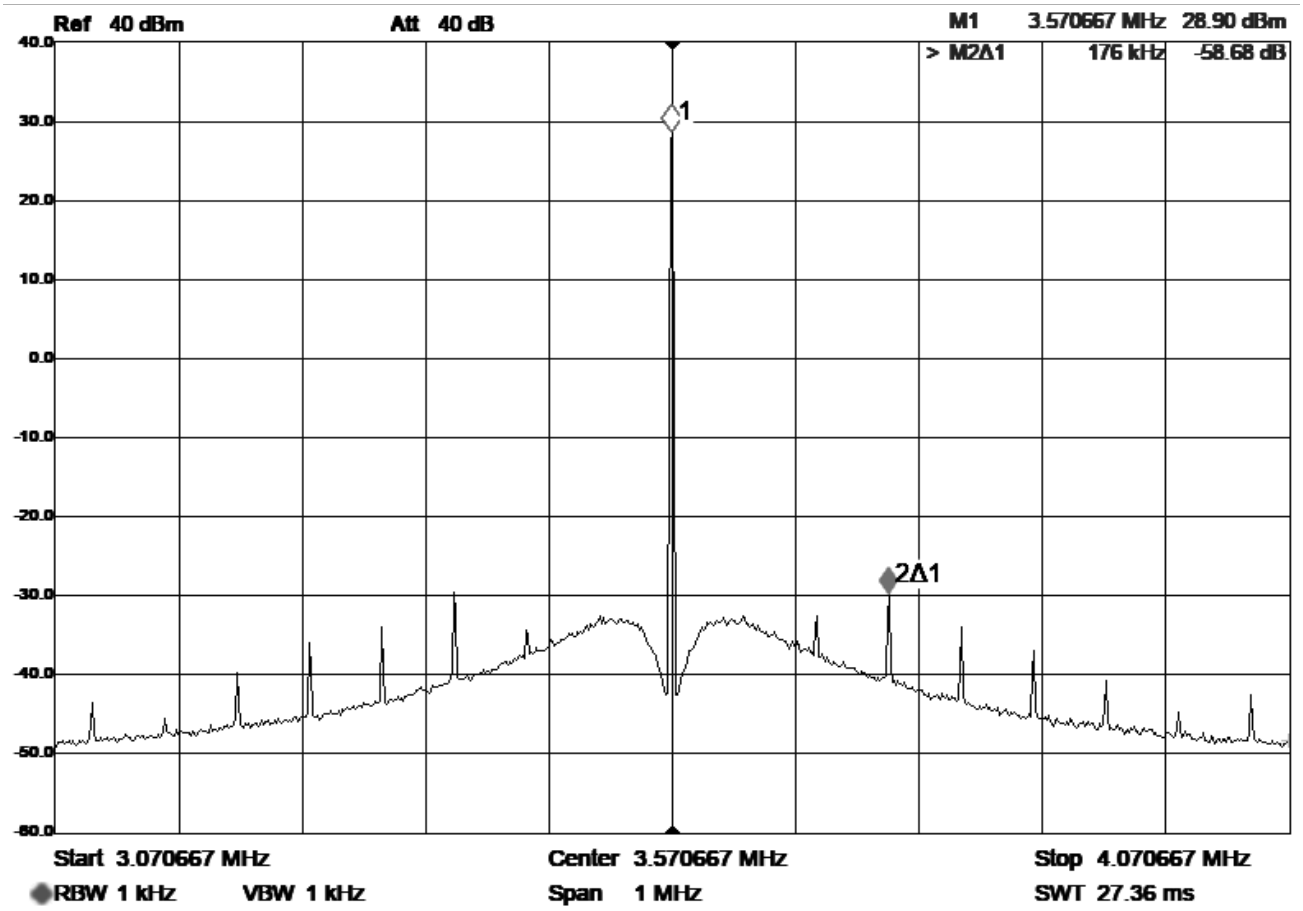


Illustration 6: 80 Meters, 1 MHz Span

40 Meters:

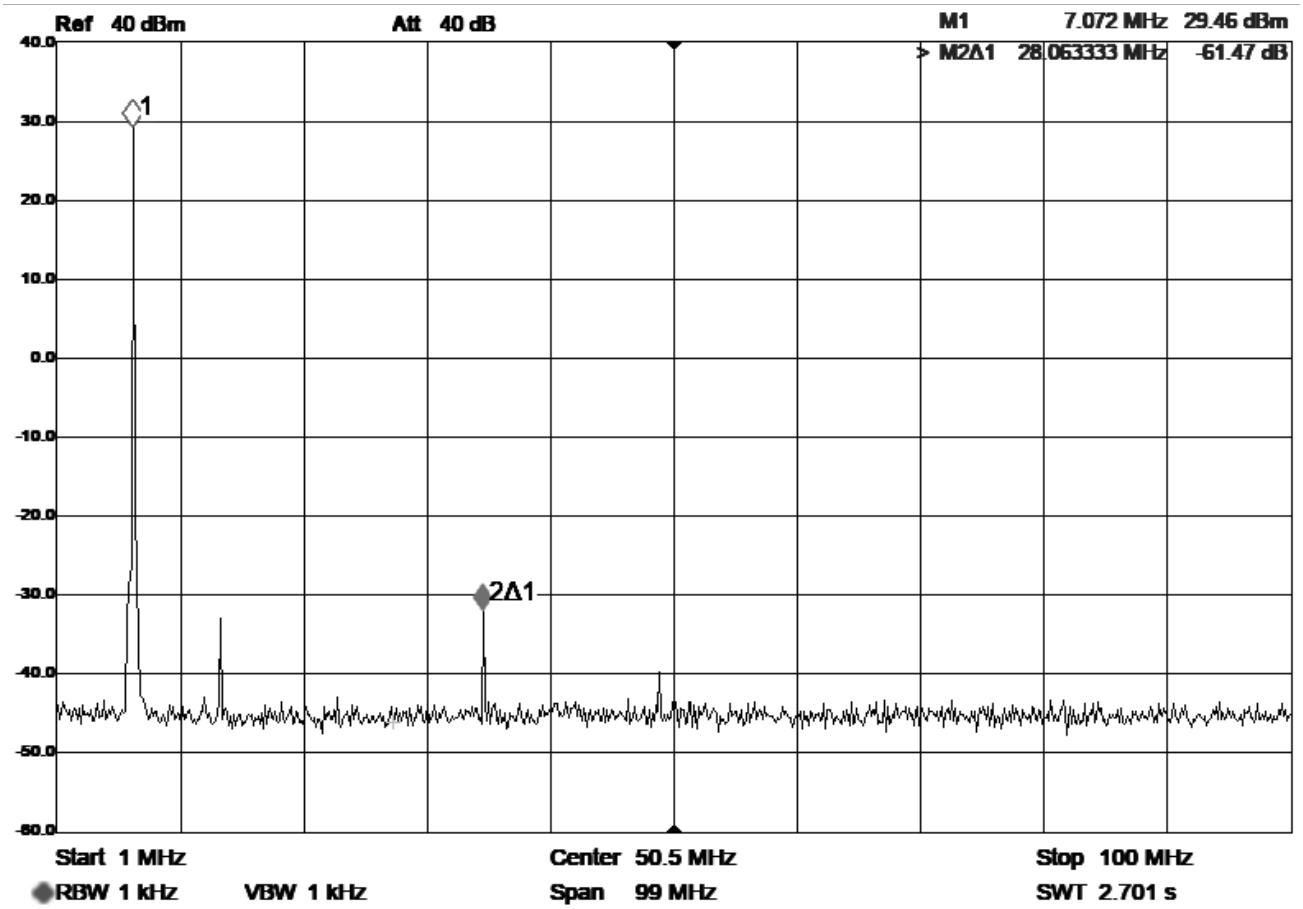


Illustration 7: 40 Meters With Filter

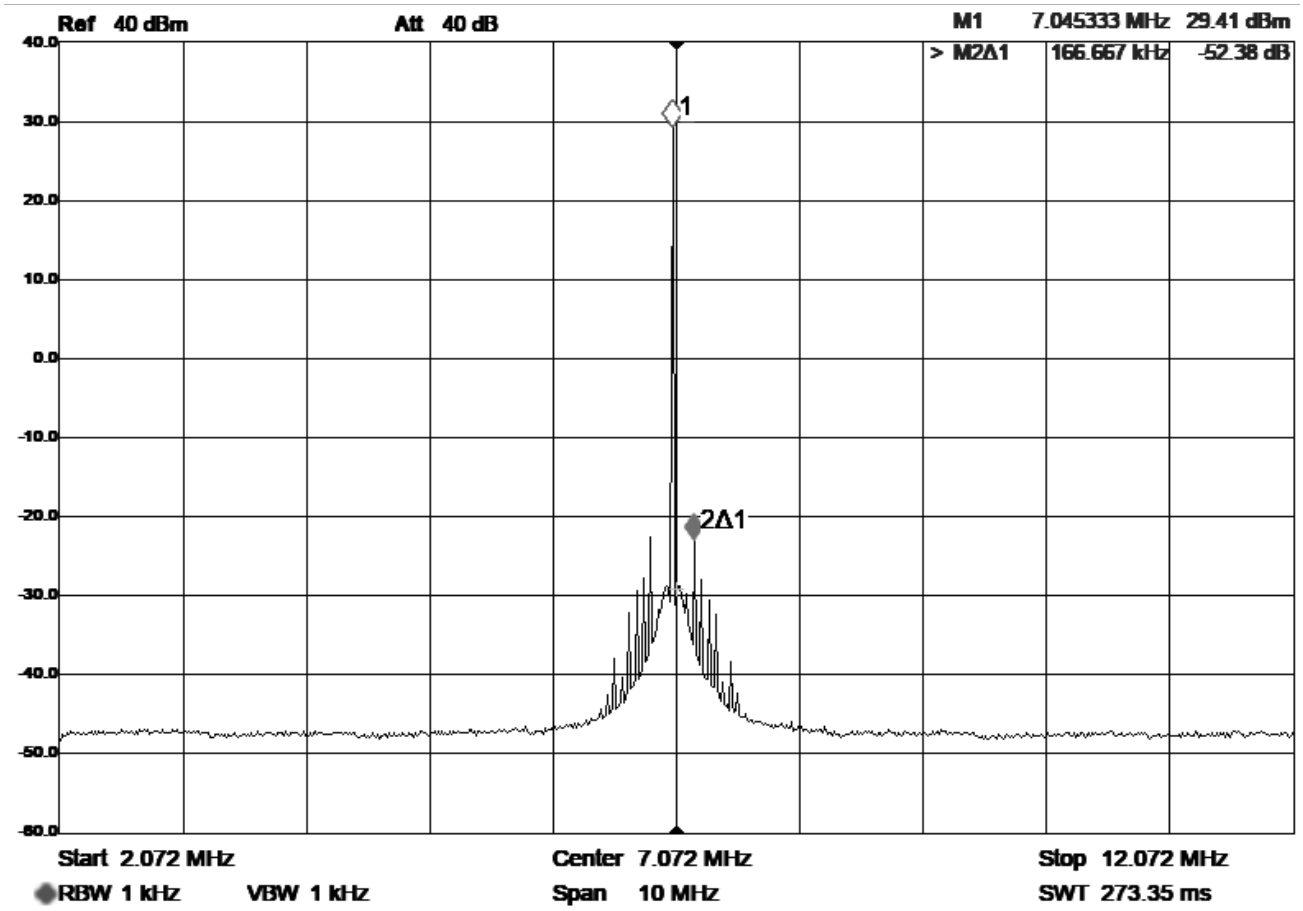


Illustration 8: 40 Meters, Span 10 MHz

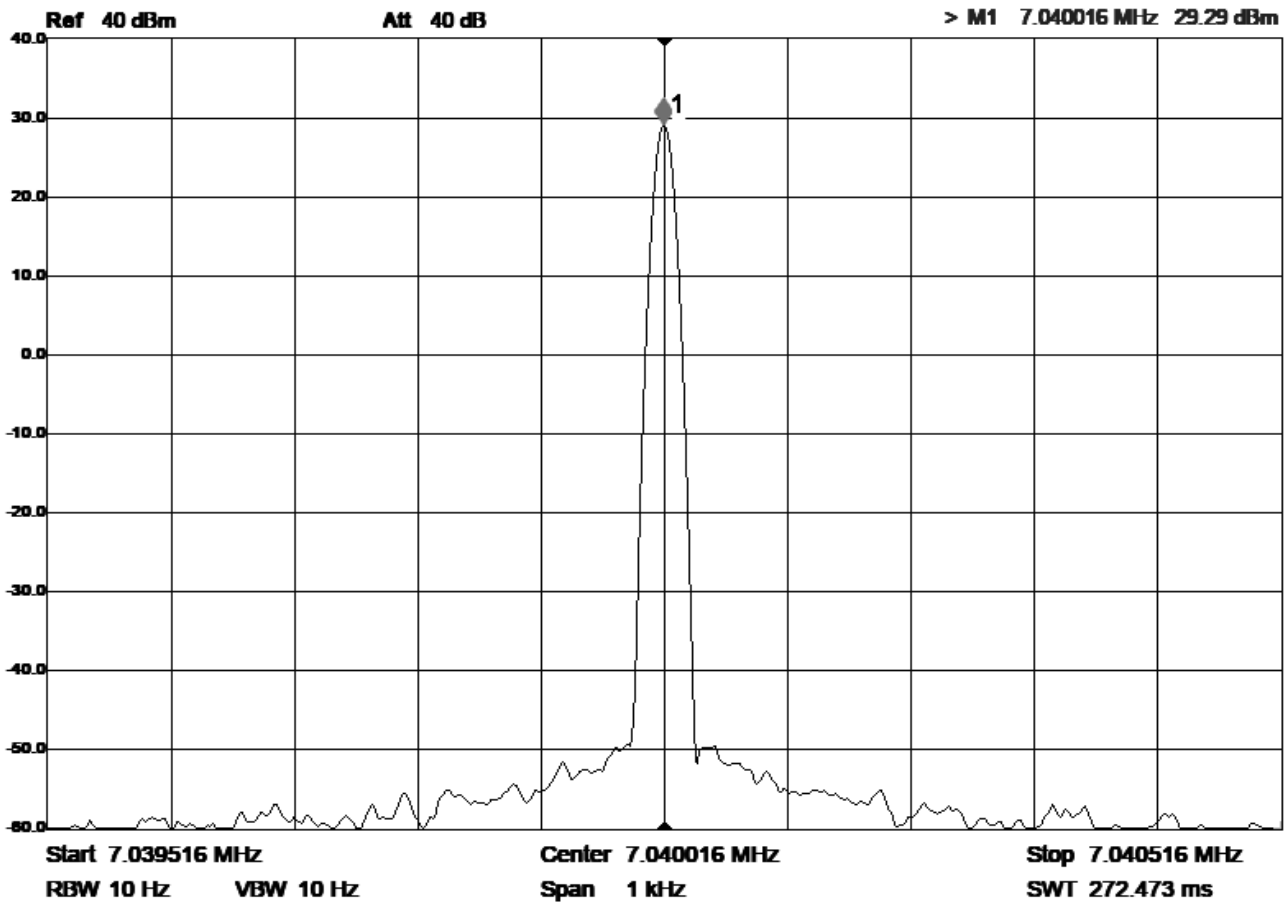


Illustration 9: 40 Meters, Span 1 KHz

30 Meters

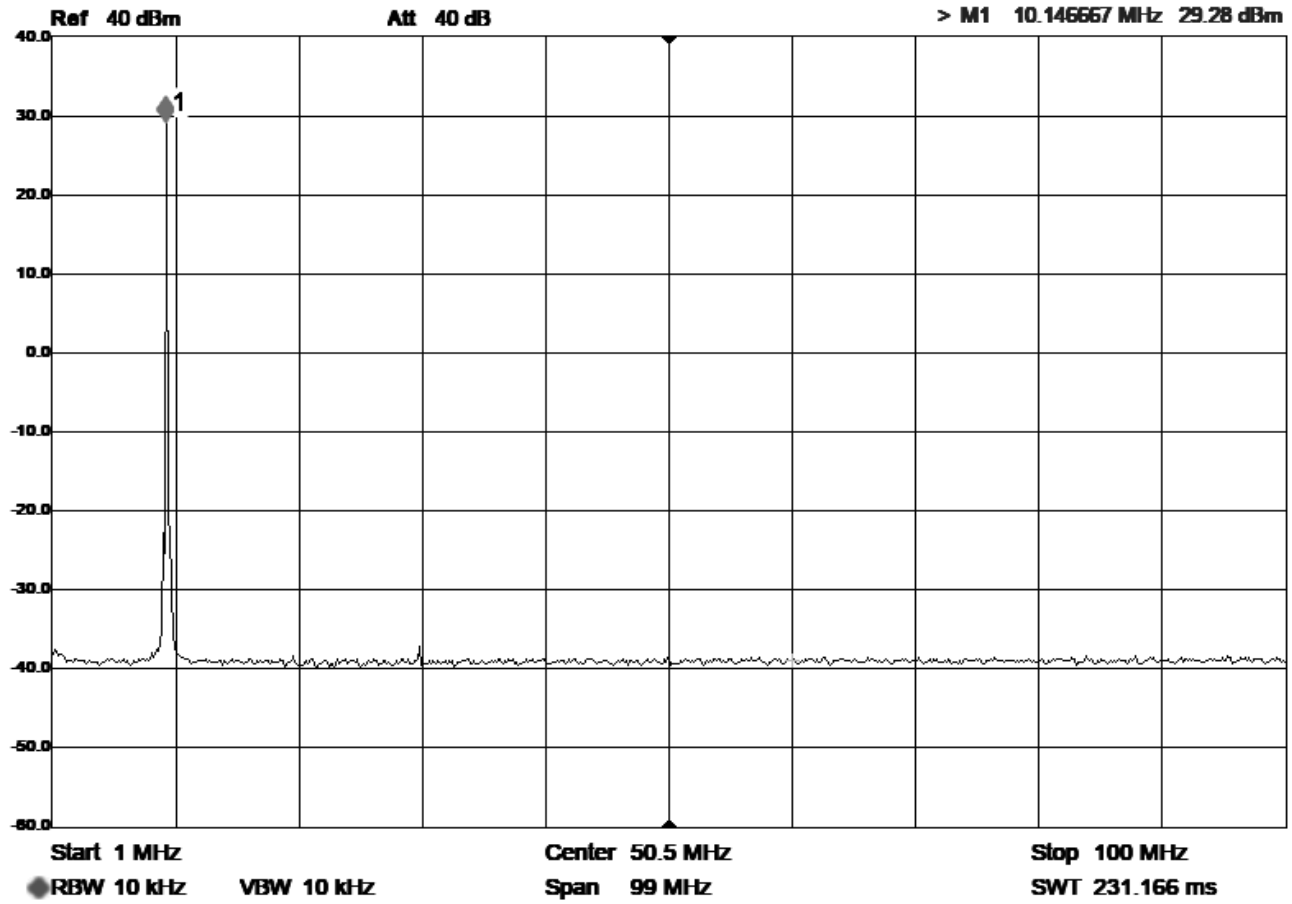


Illustration 10: 30 Meters, With Filter

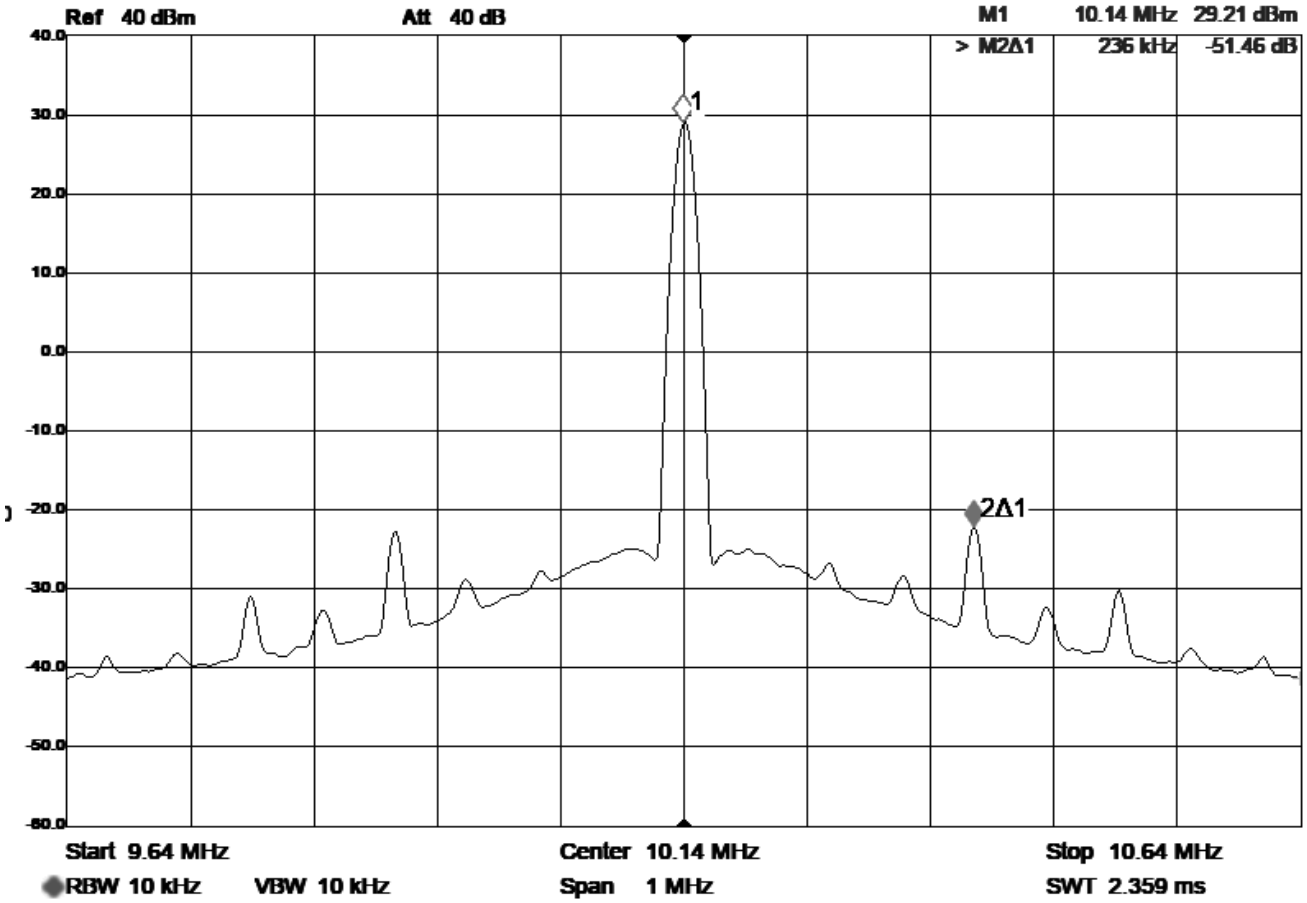


Illustration 11: 30 Meters, Span 1 MHz

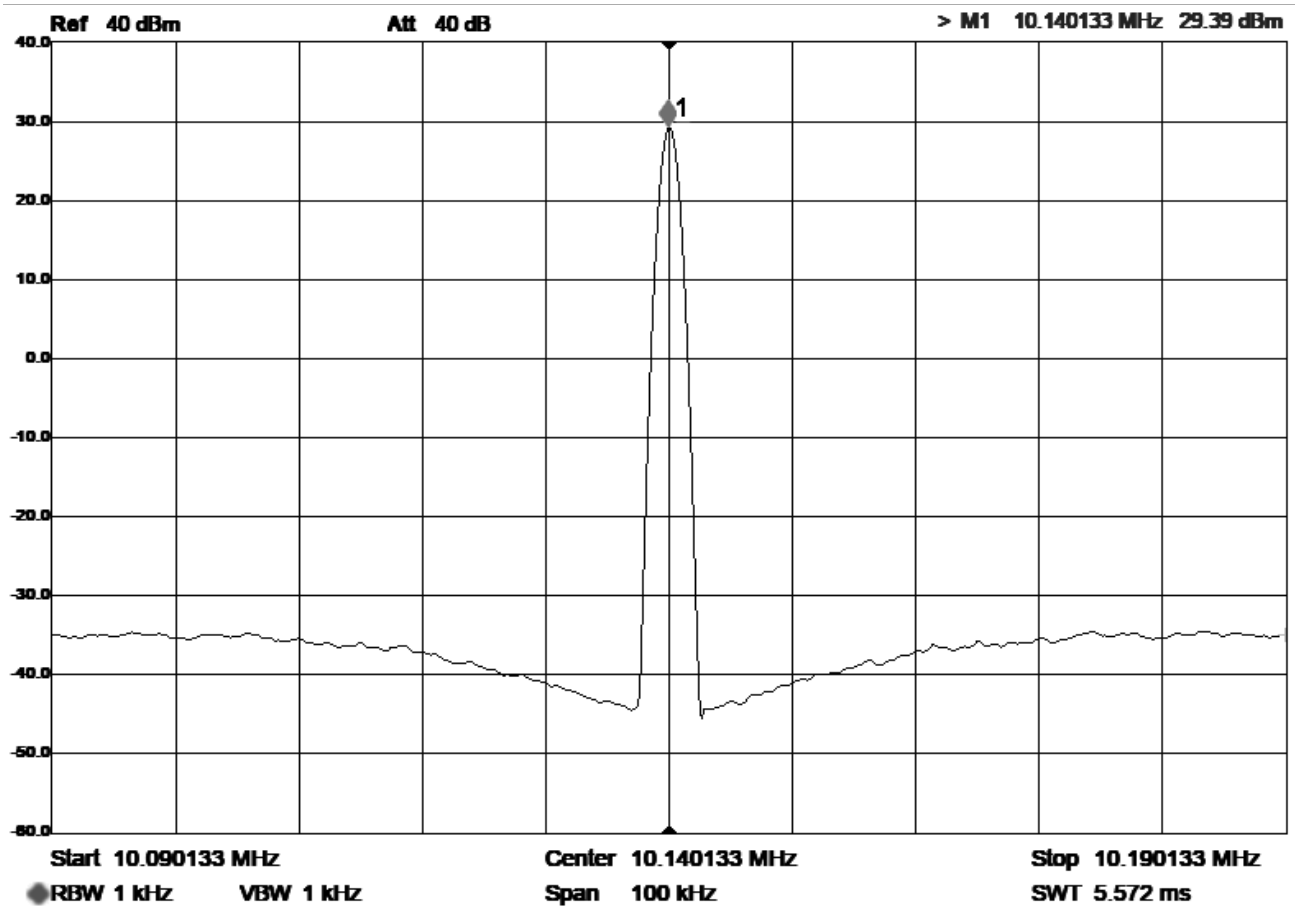


Illustration 12: 30 Meters, Span 100 KHz

20 Meters

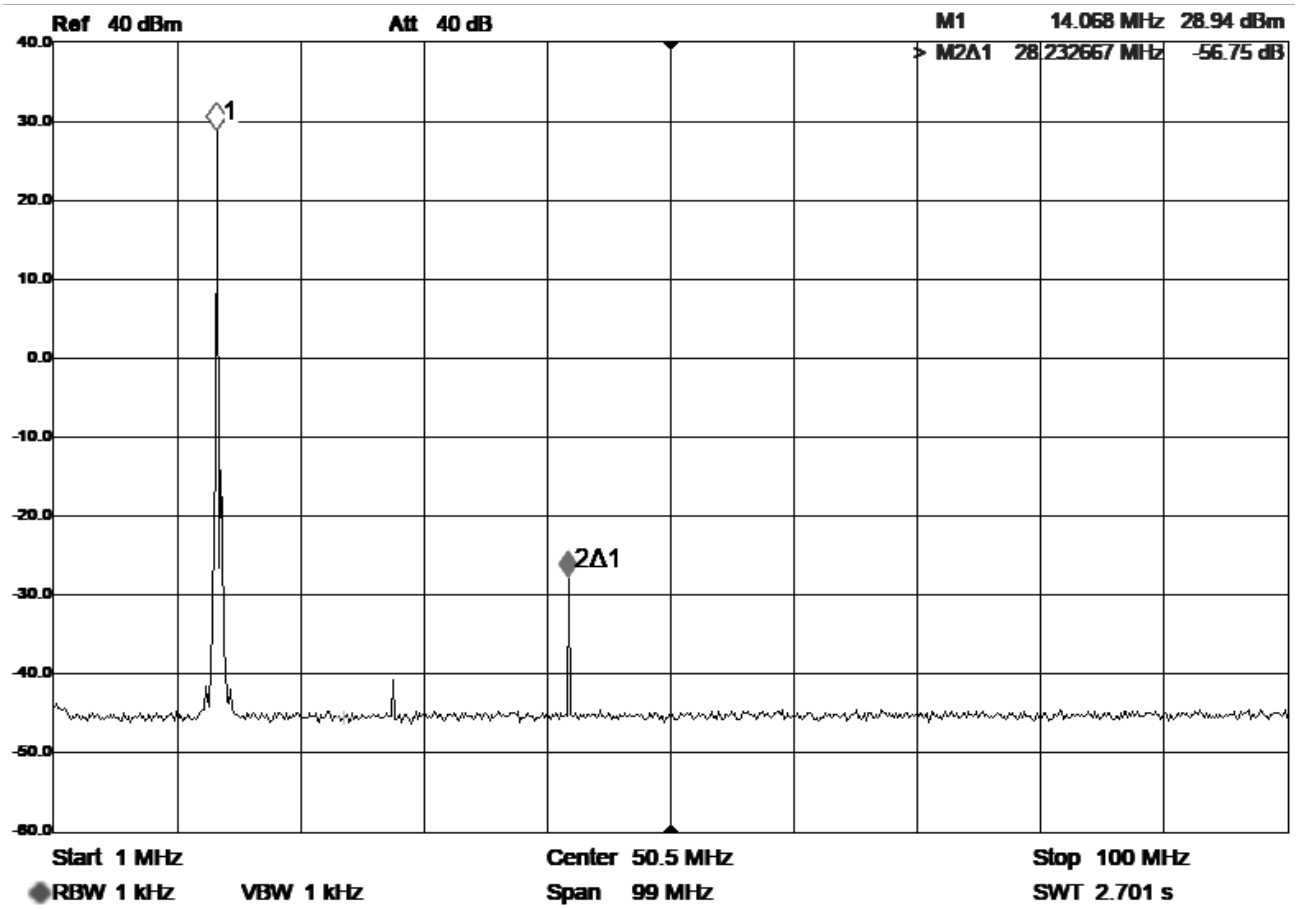


Illustration 13: 20 Meters, With Filter

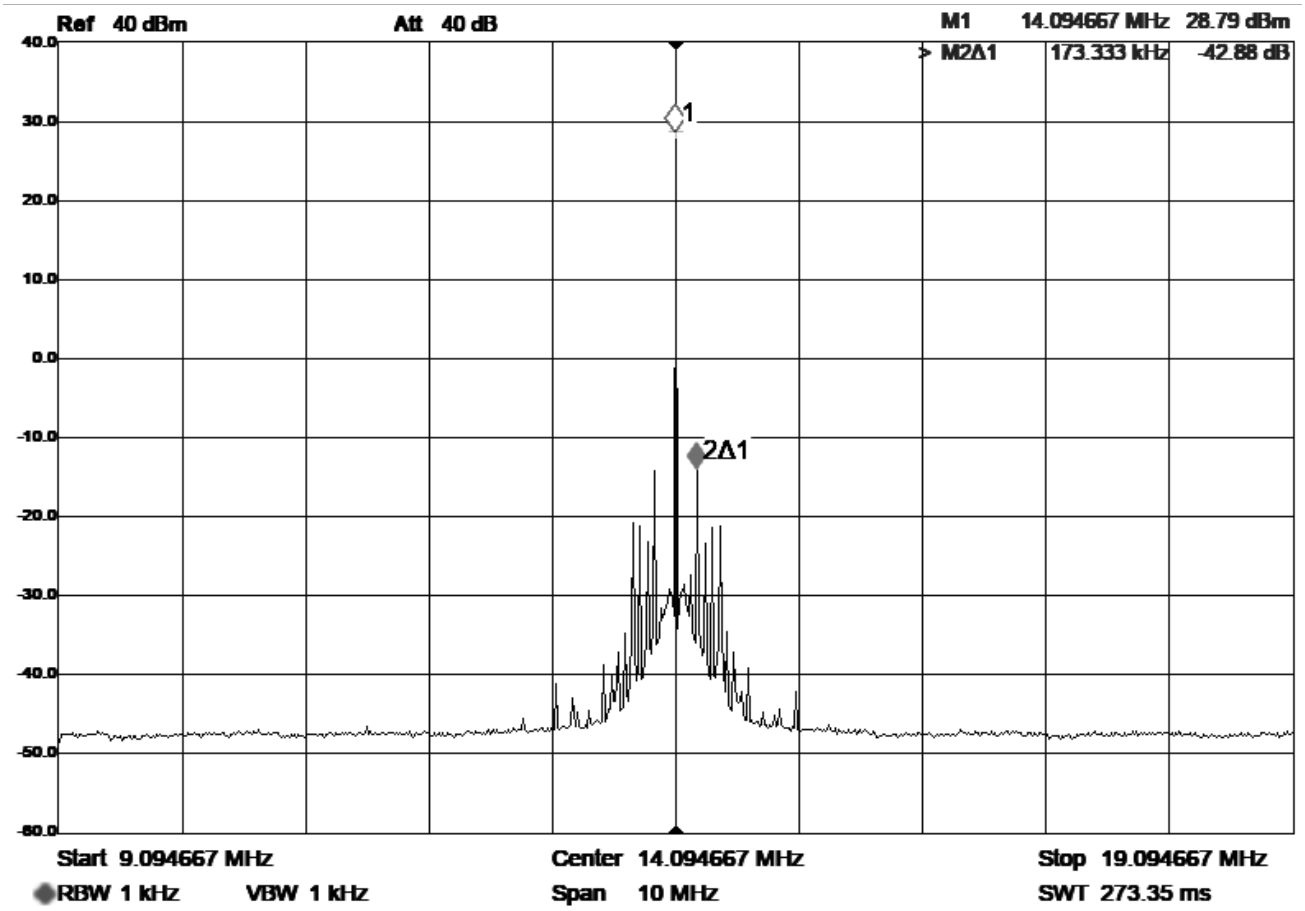


Illustration 14: 20 Meters, Span 10 MHz

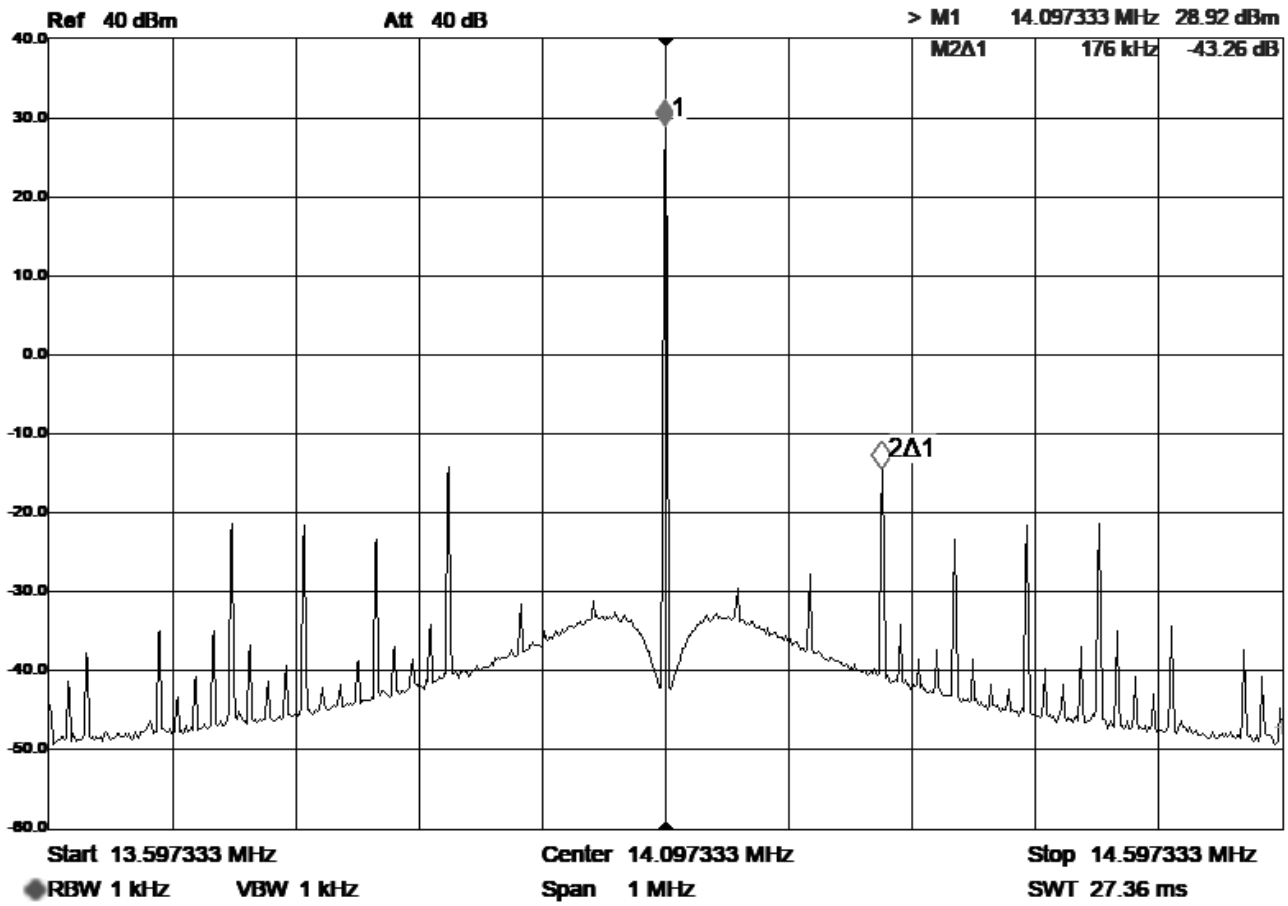


Illustration 15: 20 Meters, Span 1 MHz

Note that the close-in spurious signals are only suppressed by 43dB on the 20-meter band.

15 Meters

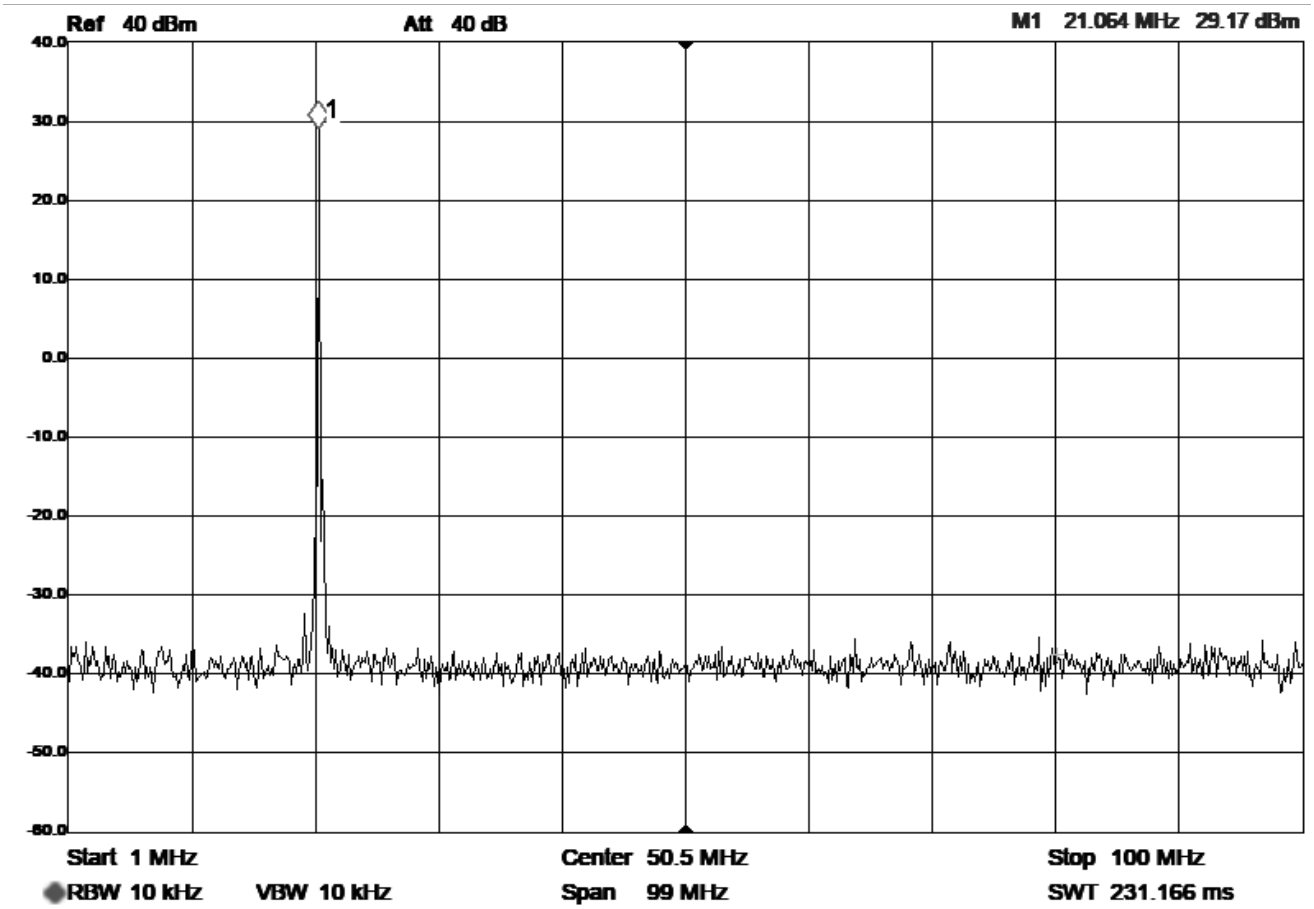


Illustration 16: 15 Meters, With Filter

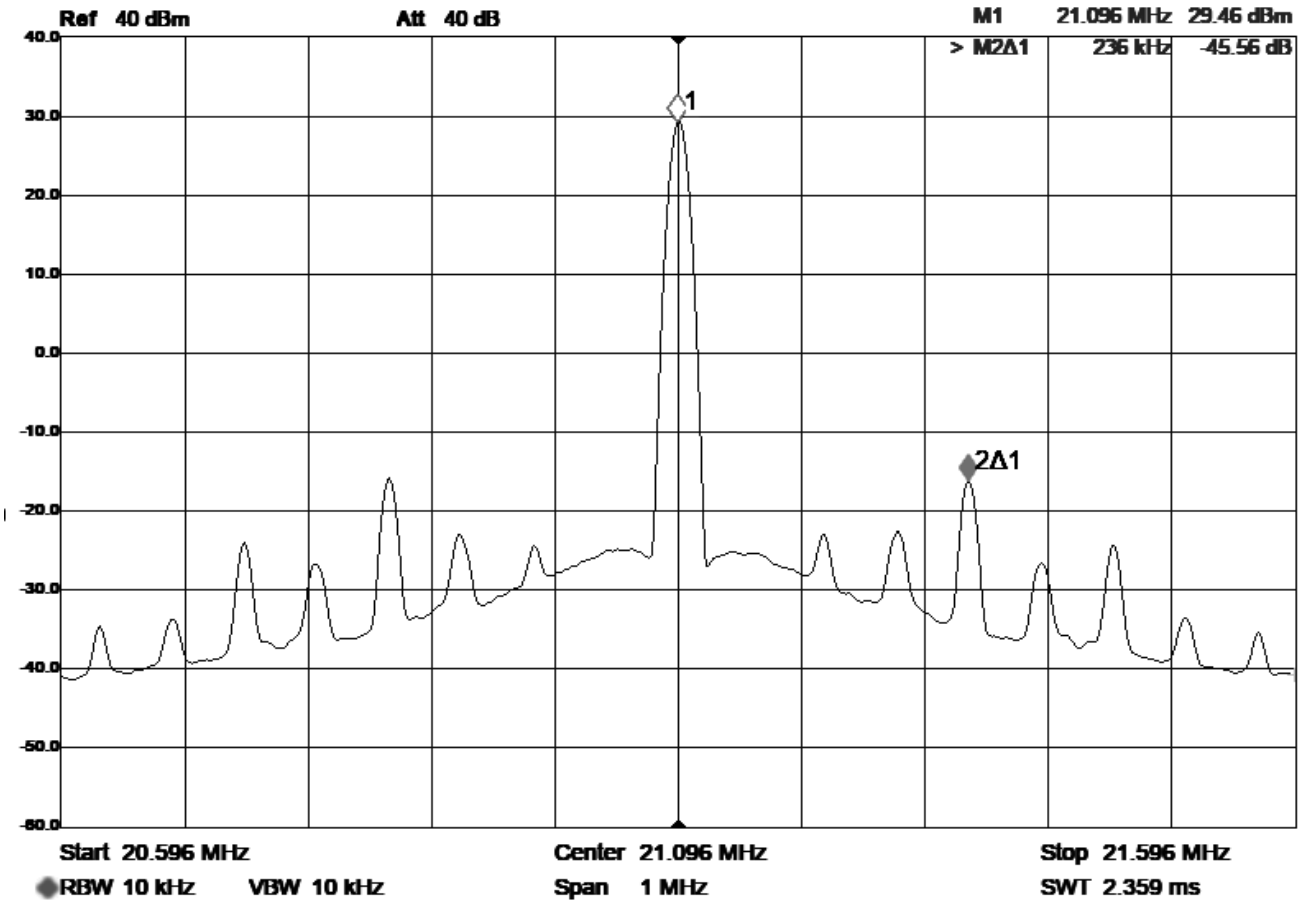


Illustration 17: 15 Meters, Span 1 MHz

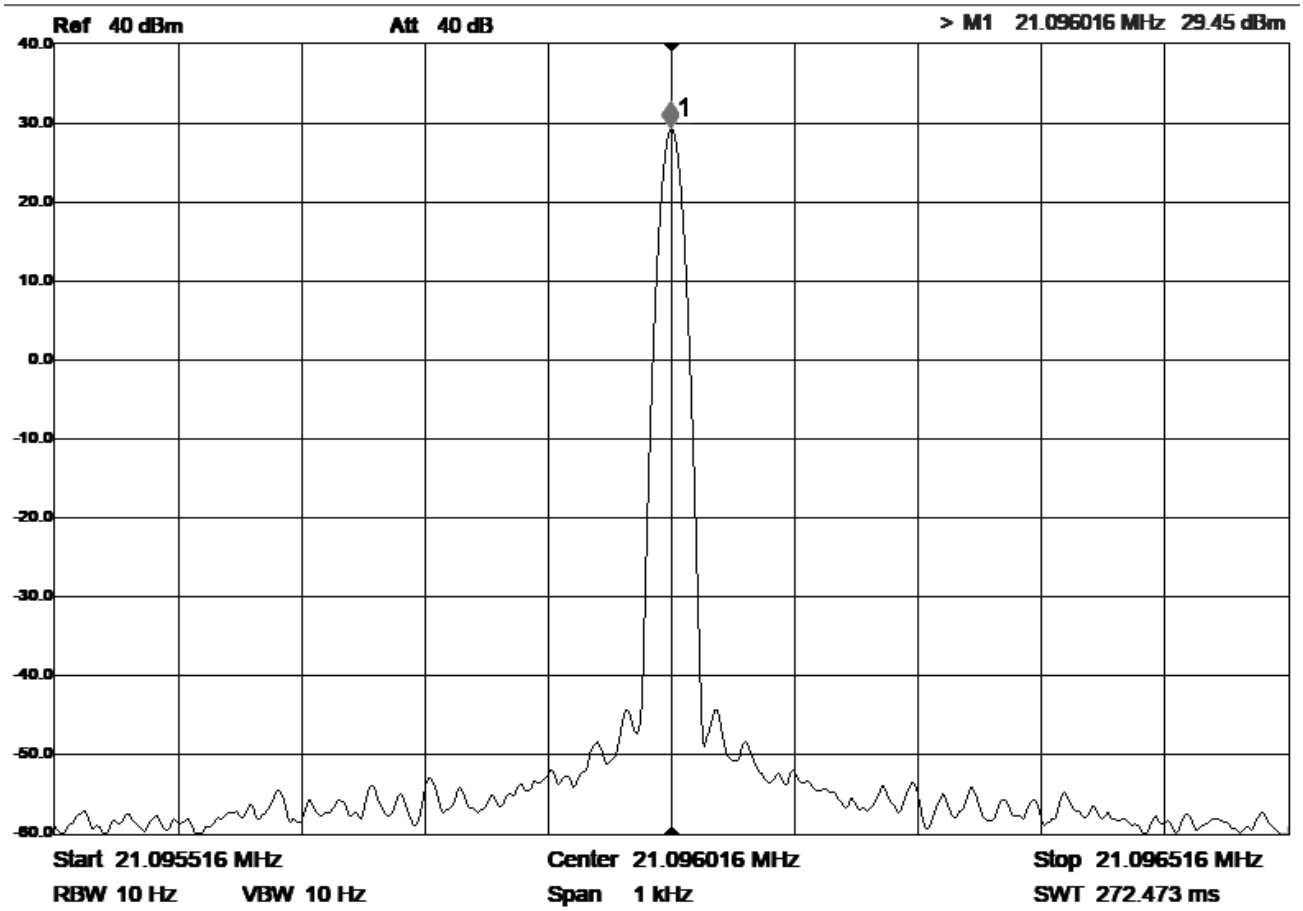


Illustration 18: 15 Meters, Span 1 KHz

10 Meters

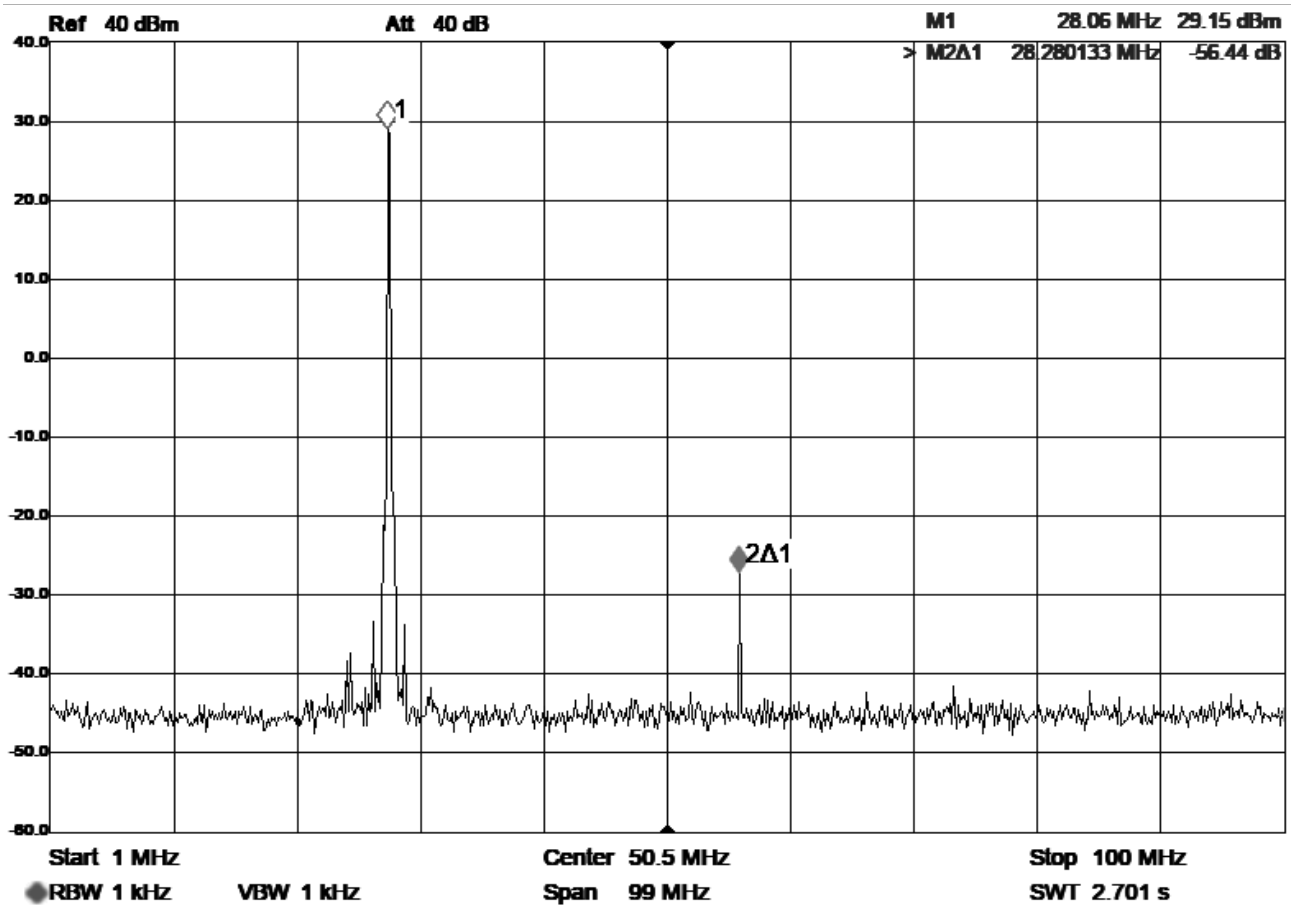


Illustration 19: 10 Meters, With Filter

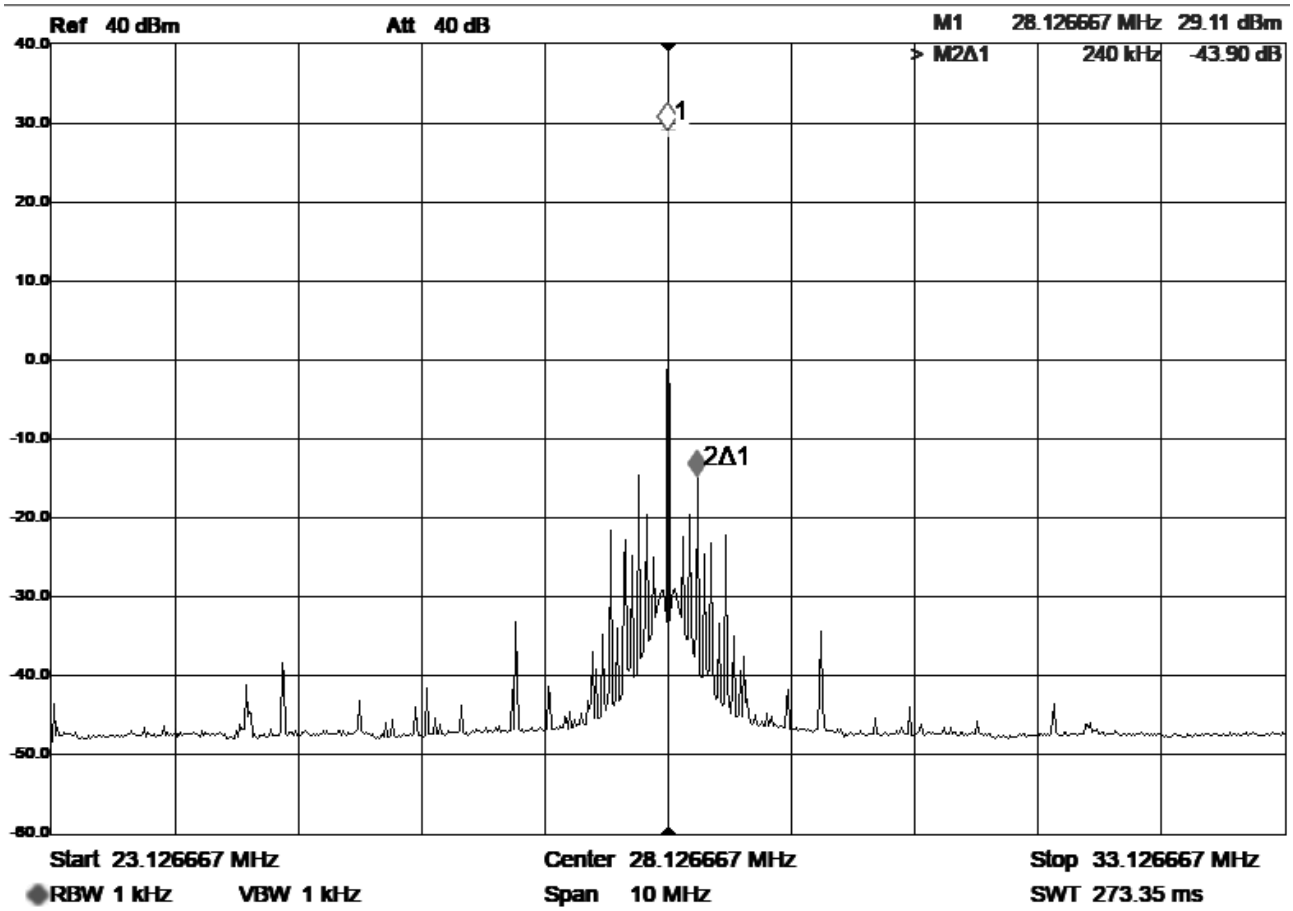


Illustration 20: 10 Meters, Span 10 MHz

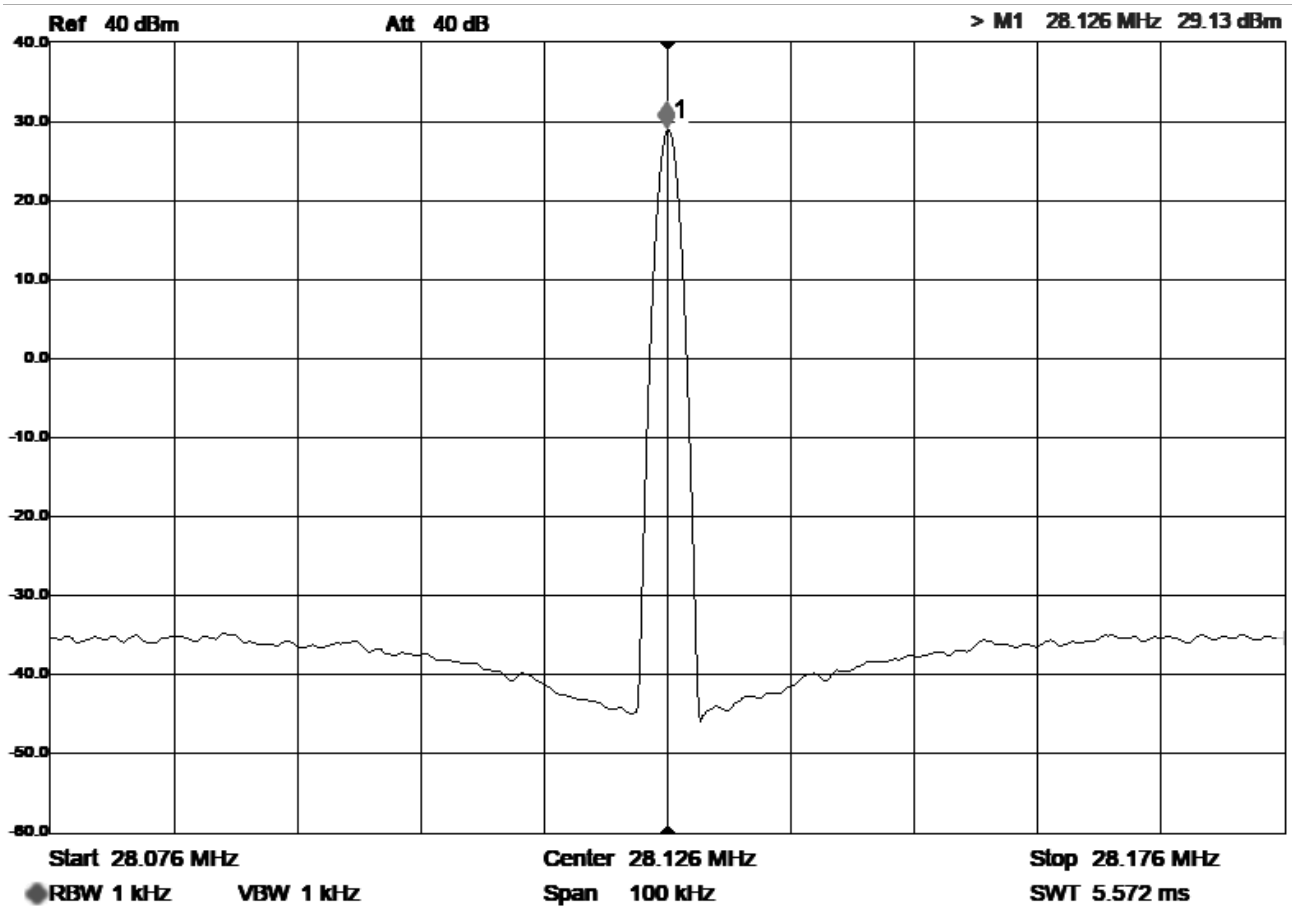


Illustration 21: 10 Meters, Span 100 KHz

Frequency Shift Keying

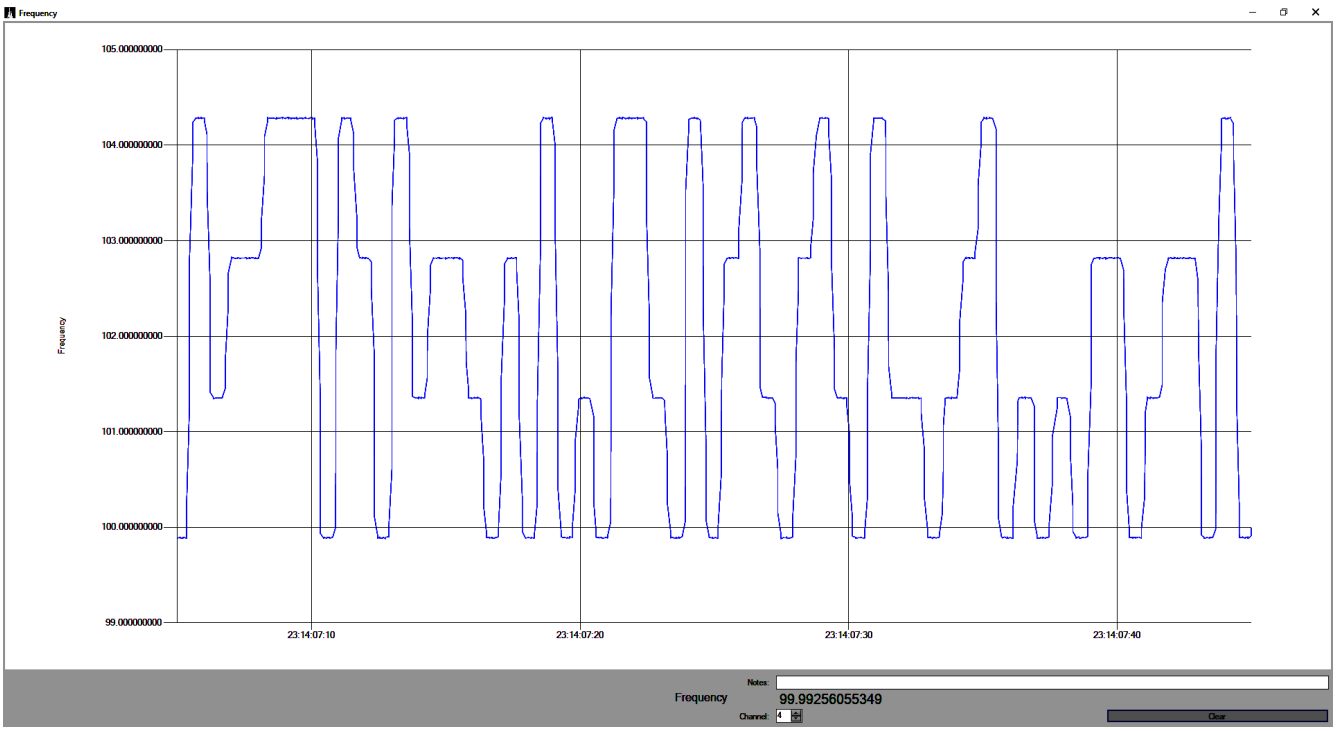


Illustration 22: 4-GFSK (Gaussian Frequency Shift Keying)

The FST4W-120 modulation is four-level FSK, symbol rate 0.683 seconds, tone spacing 1.46 Hz. More precisely, the FST4W-120 symbol rate = 12,000 Hz / 8200 = 1.463414634 Hz, and the tone spacing is the reciprocal of this.

FST4W used 4-GFSK (4-level Gaussian Frequency Shift Keying). GFSK is described here:

For a good introduction to FST4W and GFSK, see **FST4 Qucik Star**t and **FT4_FT8_QEX** here in the App Notes section: https://turnislandsystems.com/downloads/

Please note that FST4W uses a Gaussian filter with a “BT = 2”, rather than the slower “BT = 1”. While the FST4W spec also includes a filtered amplitude ramp up and down at the start and end of transmission, the BB-6 does not implement this. In theory this will cause “key clicks” a the start and end of the transmission, but in practice these are barely noticeable.

FSK Modulation Method

Description to come of the Si5351 PLL and output divider A + ((B – k) / (C - k))

Gaussian Filtering

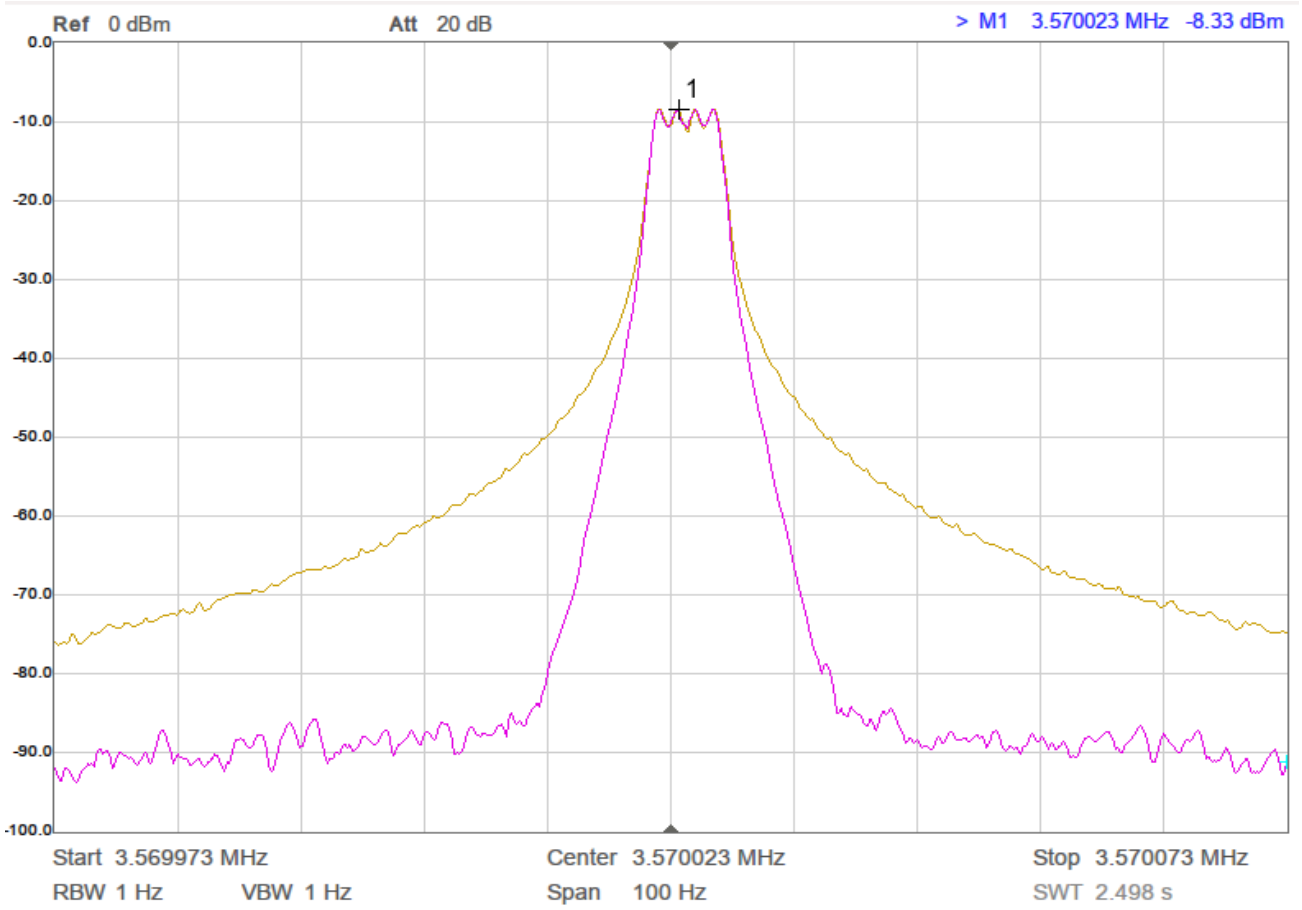


Illustration 23: Gaussian Filter On / Off

Here you can see the spectrum of the Gaussian Frequency Shift Keying (GFSK) and unfiltered Frequency Shift Keying (FSK). There is little difference until you get below -20dBc, but after that the modulation artifacts become quite obvious, and an unfiltered FSK signal will interfere with neighboring transmissions.

In fairness, while FST4W specifies GFSK, WSPR uses unfiltered FSK. With WSPR there is some filtering effect caused by the traditional SSB modulation technique, where the 3 KHz audio bandwidth attenuates the modulation sidebands, but this will not be apparent in the narrow-span measurement shown here.

Many WSPR and FST4W “direct digital” beacons generate unfiltered FSK for both WSPR and FST4W, and no ill effects have been noticed (although the “signal subtraction” decoder in the WSJTX program supposedly does better with GFSK signals.) The BB-6 uses GFSK just because it seems the proper thing to do.

You can enable (and disable) the BB-6 Gaussian Filter through the configuration file or the command-line (see the command list). The default is “filter on”.

This filter is implemented in software, with a frequency update rate of 41 x the symbol rate (which happens to be 60 Hz.) The available frequency steps vary from band to band, but

range from 3 to 440 steps per shift. Even with only three steps per shift, the filtering makes a dramatic improvement in the sideband level.

Test Modes

[test mode commands info goes here]

Make Your Own Filter

The BB-6 outputs are square-wave, and so have strong harmonic components that must be attenuated. The Filter/Combiners use series band-pass sections, which permits the several filter outputs to be connected with minimal interaction.

But a basic single-band filter need only be a low-pass design. While the typical capacitor-input “C/L/C Pi” network will work, the shunt capacitor at the filter input will cause heavier loading of the amplifier than necessary. A better option is to use an inductor-input “L/C/L Tee” design. The filter need not have a lot of attenuation at the second-harmonic, as this is generally already down below -30 dBc. But filter attenuation at the third and higher odd harmonic frequencies should exceed 30dB at a minimum.

Here is an example filter for the 80-meter band. It includes a 3'rd harmonic notch, improving the overall filter performance where it counts:

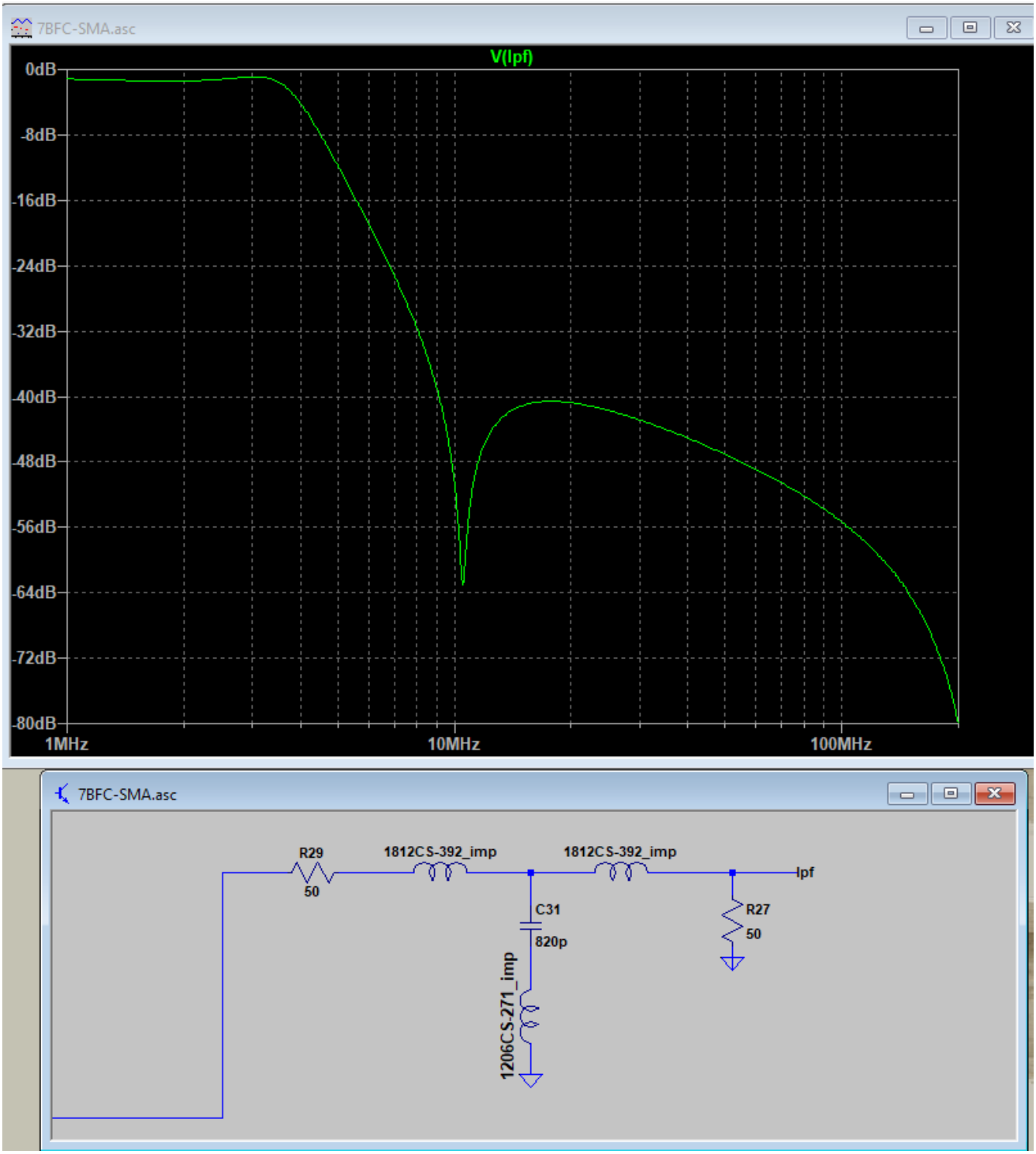


Illustration 24: Single-Band Filter Example

The series inductors (CoilCraft surface-mount style) are 3.9 uH, the shunt inductor is 270 nH.