Nine-Band Filter-Combiner

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Introduction

This document covers the Turn Island Systems Nine-Band Filter-Combiner (9BFC).

While the 9BFC is discussed here in the context of the WSPRSONDE, it can also be used to filter low-power signals (1W or less) from other transmitters, be the outputs square or sine waves. The filter is a bidirectional device, and may be used between an antenna and receiver if desired.

For a more detailed review and analysis of the various Turn Island filters and filter-combiners, please see the document “Filters and the Filter-Combiner”

(https://turnislandsystems.com/wp-content/uploads/2024/04/FC-2-1.pdf)

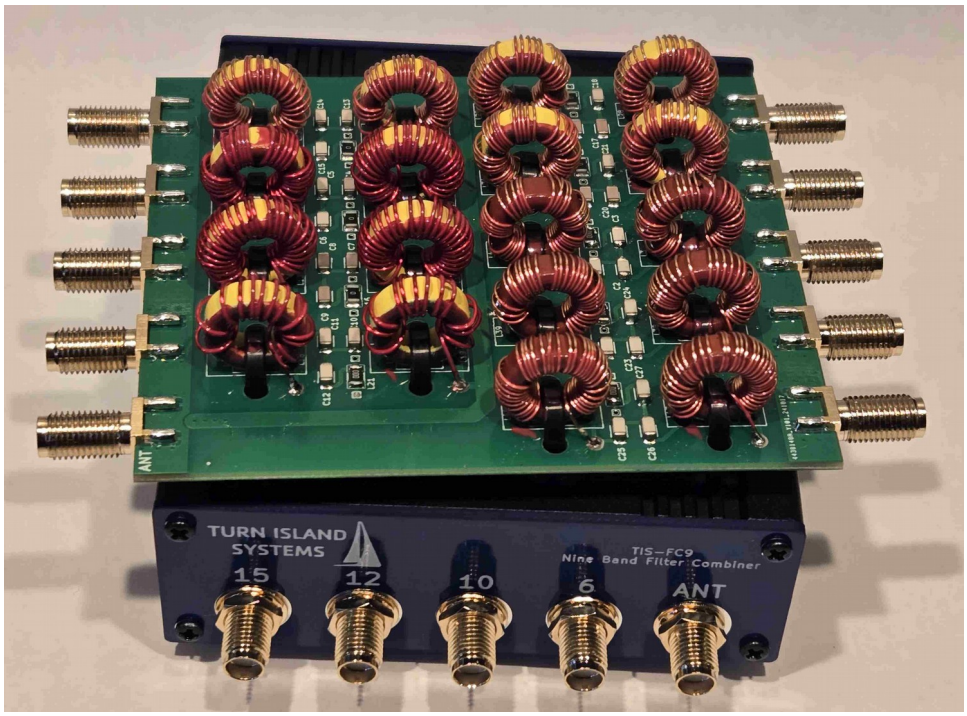
Overview

The 9BFC uses a bank of filters to allow multiple transmit signals to be simultaneously connected a common multiband antenna. These filters also attenuate transmit harmonics, which is essential when

using a transmitter such as the WSPRSONDE having frequency-flexible square wave outputs (square waves contain significant odd harmonics, as well as some even harmonics in the real-world non-ideal case).

Details

The 9BFC has nine input ports, each connected to a band-specific bandpass filter, and one common output (antenna) port. The bands supported are 80, 40, 30, 20, 17, 15, 12, 10, and 6 meters, with filter frequencies centered on the established WSPR sub-bands.



Each of the nine filters consists of two series-resonant sections, with a shunt capacitor as the coupling element (this has been called a “Mesh-C-coupled bandpass” filter). The filters are as wide as possible in order to minimize filter loss, and the response is slightly over-coupled to provide a somewhat flat-top response. As the various bands are not evenly-spaced some of these filters need to be narrower than others.

The filter bandwidth is also designed to minimize filter interaction and reduce adjacent-port coupling to -20dB or better

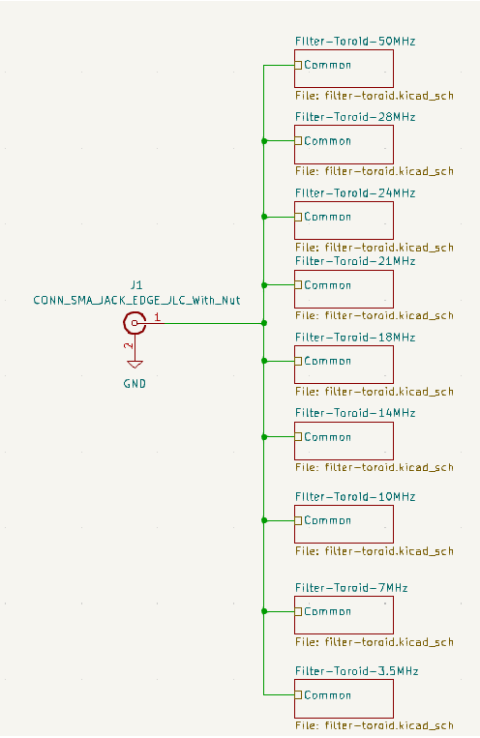
Where the TIS filter-combiners using surface-mount inductors include a shunt inductor to create a tuned 3'rd harmonic notch, the 9BFC filters are sharp enough that this notch is not necessary and so the additional inductor is not used. As the filter-response plots show, the 3'rd harmonic is typically reduced to better than -65 dBc.

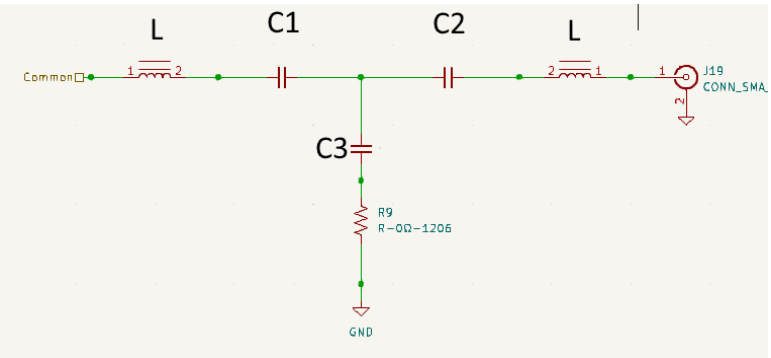
Hand-would toroid core inductors are used as these provide a higher “Q”, enabling these narrow filters to be designed with lower loss than would be the case with the available surface-mount inductors as used in the Turn Island Systems filter-combiners designed for more widely-spaced ham bands.

These toroid inductors require hand-tuning during assembly and test, to allow for component tolerances and winding variation – necessary in these narrower filters.

The toroids are also more able to handle the excessive RF current conditions seen in high SWR conditions as when the antenna port is left open (the filter circuit transforms a high impedance to a low one), or the antenna is badly mismatched. The surface-mount inductors can get uncomfortably hot during these conditions, where the toroids merely get warm.

Circuit Description





The zero-Ohm resistor in this schematic takes the place of an optional surface-mount inductor which is not needed in the 9BFC.

Filter Performance

Below is the simulated response of each of the nine filters:

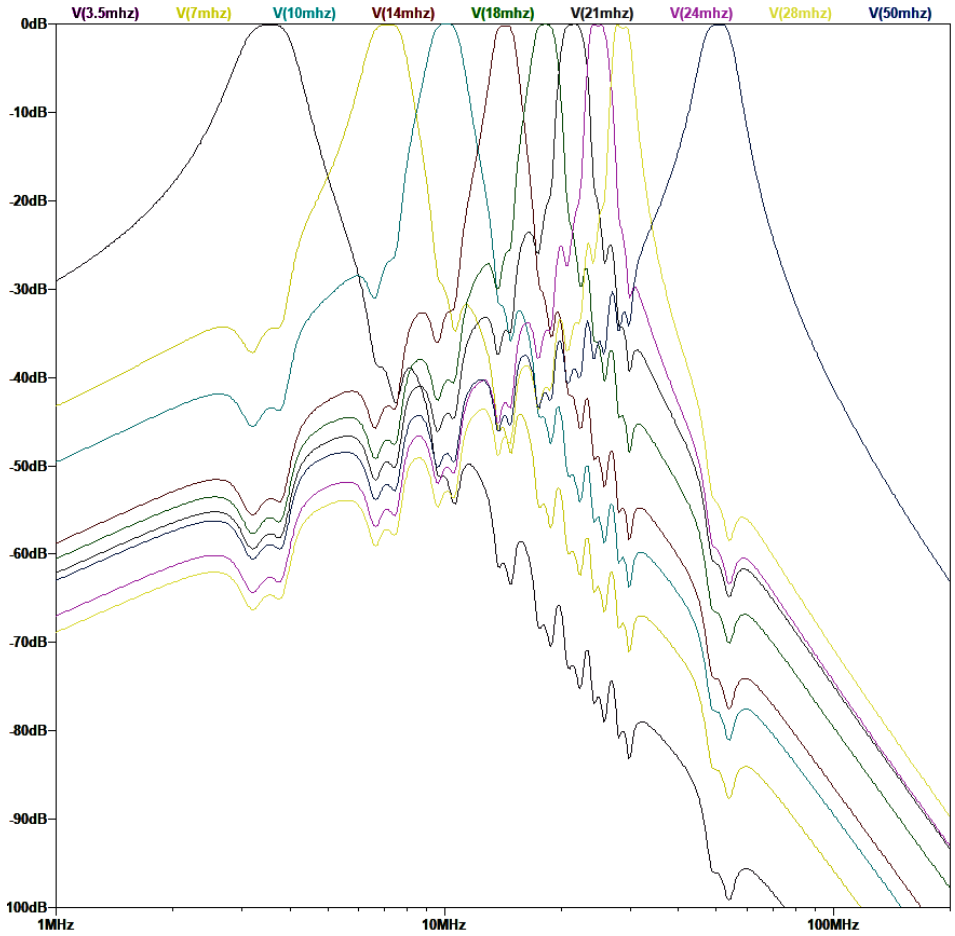


Illustration 1: Simulated filter response

This simulation uses ideal (lossless) inductors, but the toroids used do have some loss, and the actual filter loss is roughly 1dB at the center frequency.

Shown below are typical 9BFC outputs (into a 50 Ohm load), when driven by the WSPRSONDE. The 1W square waves are filtered to reduce the 2'nd harmonic to better than -60dBc, and the 3'rd (and higher) harmonics well below that. When all eight channels (80-10 meters) are enabled the full output spectrum meets all amateur radio requirements. There is some low-level IMD exhibited, which is due to transmitter interaction via the 9BFC port-port coupling. This level of IMD is also well under the legal limits.

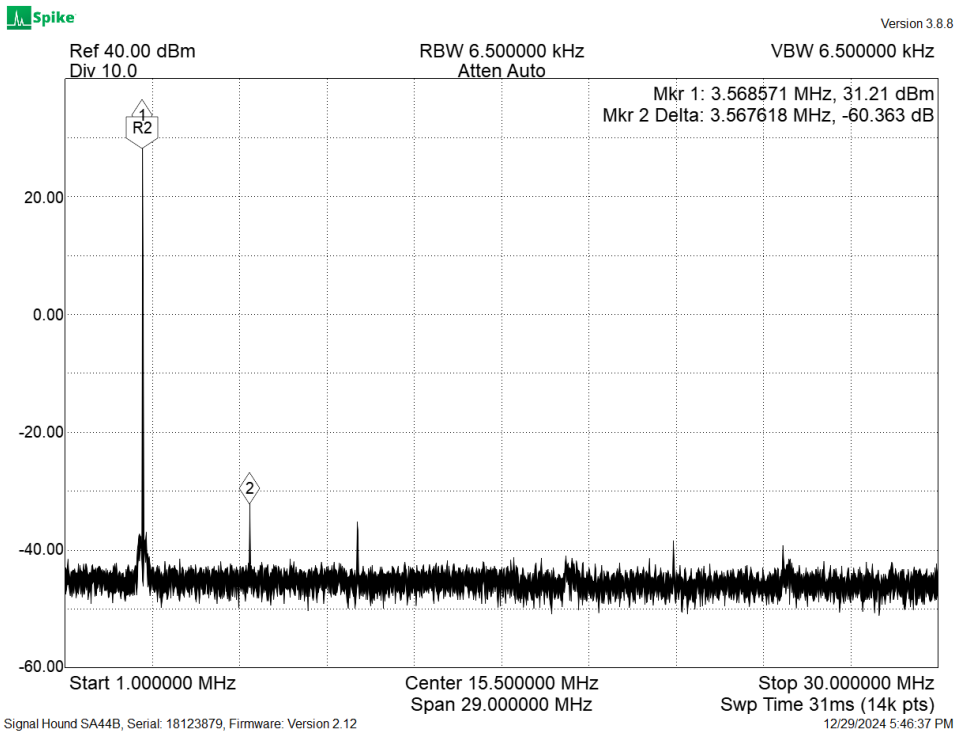


Illustration 2: 80 meter spectrum, 1W square wave input

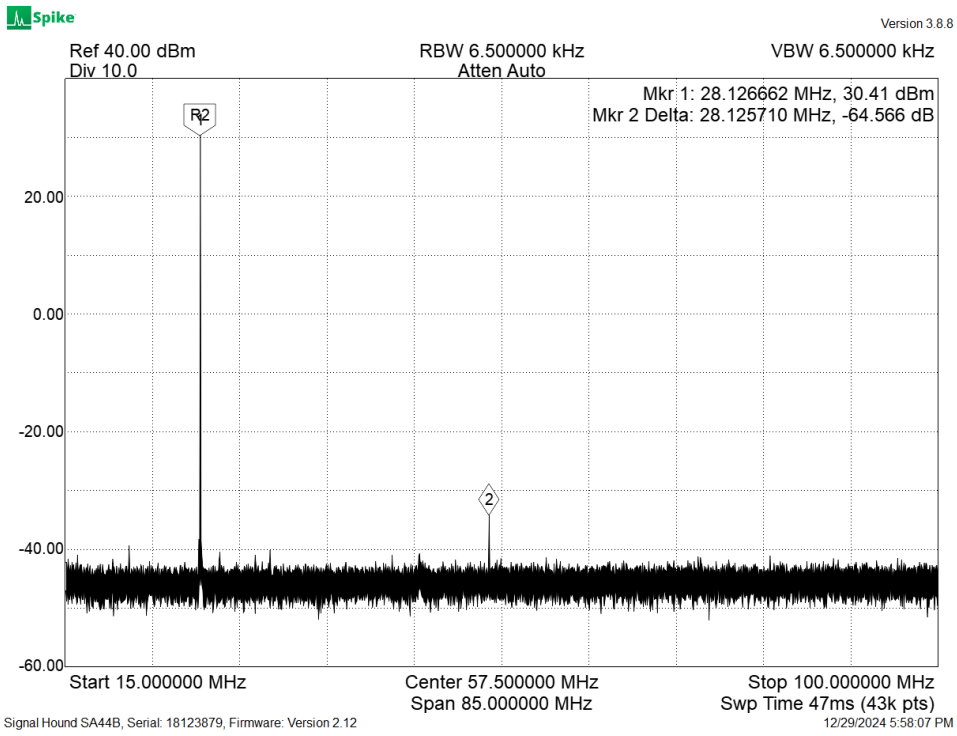


Illustration 3: 10 meter spectrum, 1W square wave input

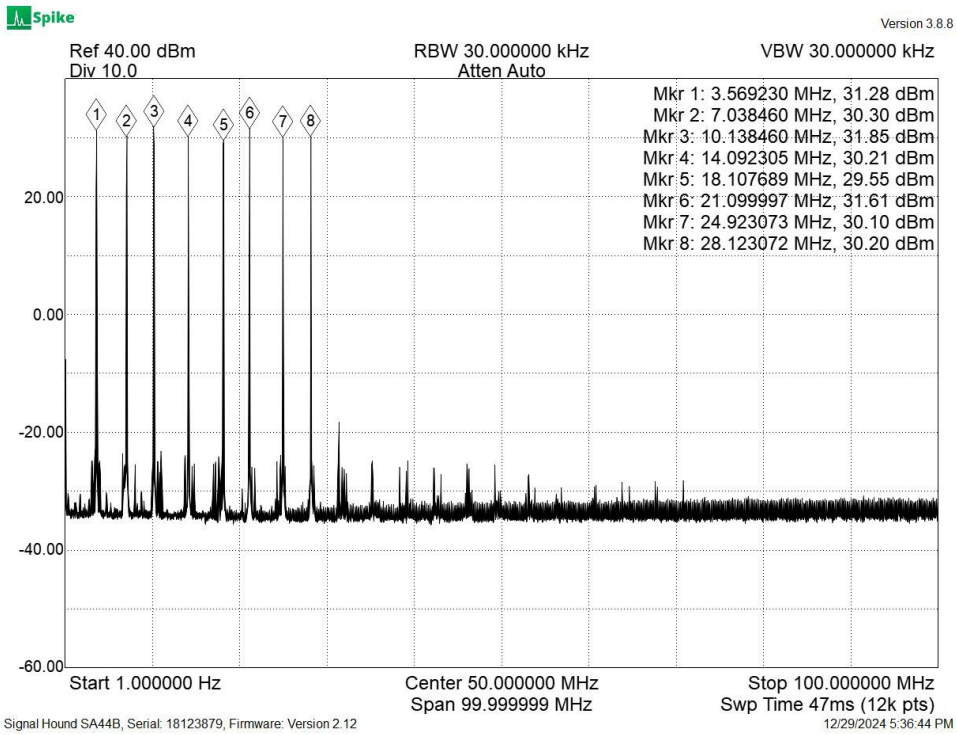


Illustration 4: 80/40/30/20/17/15/12/10 meter output, 1W square wave