Elliptic Low Pass Audio Filters

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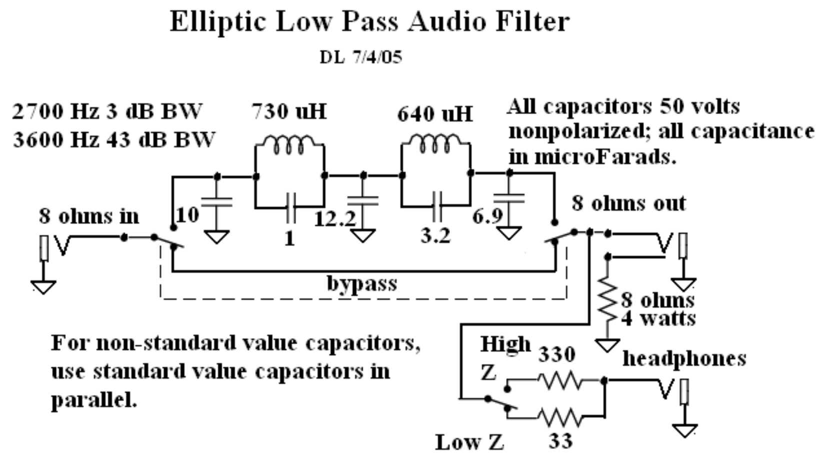
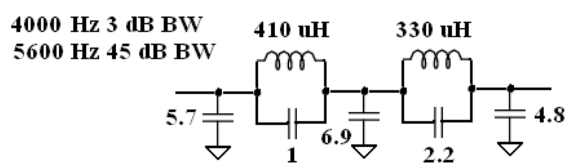
There are a number of different accessories which claim to improve recovered audio from strongly fading MW and SW signals, including various audio filters and AM synchronous detectors, and for which designers, sellers, and users have often given glowing praise. But according to my ears there is only modest improvement due to these kinds of devices when the receiver used with these devices has a suitably slow AGC release time. The distortion which one hears from strongly fading MW and SW signals manifests itself as high frequency sound akin to noise. So it would seem that an appropriate low pass audio filter should substantially improve the audio quality of strongly fading MW and SW signals. However, the audio filters I tried did not. I suspected that either the cutoff frequencies of the filters were not appropriate, or the shape factors (roll off) of the filters were not appropriate, or both, or that other factors were responsible for the lack of significant audio improvement. Also, many audio filters roll off the low frequencies, giving the recovered audio a tinny sound, which degrades audio quality in my opinion. And some digital filters, such as the Timewave DSP-599zx filter which I used some time ago, have annoying digital artifacts. Rather than spend thousands of dollars for audio filters with variable cutoff frequencies and steep attenuation roll off, such as the Stanford Research 640, which still might not be satisfactory and which might require additional circuits, I decided to design and build such audio filters myself; see the schematics above.



Option

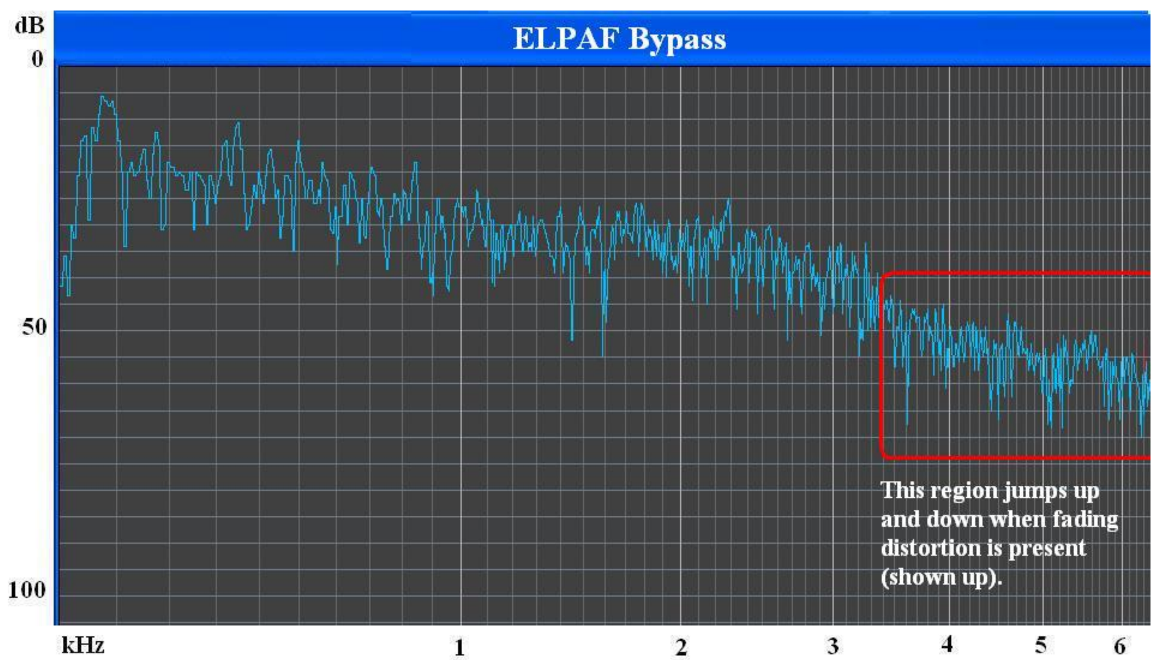
A wider BW filter does not improve recovered audio as much as the 2700 Hz BW filter above. Nevertheless, below is a 4000 Hz BW filter for those who desire one. It can be used in place of the bypass, or as a 3rd option as I did for two of the prototypes.



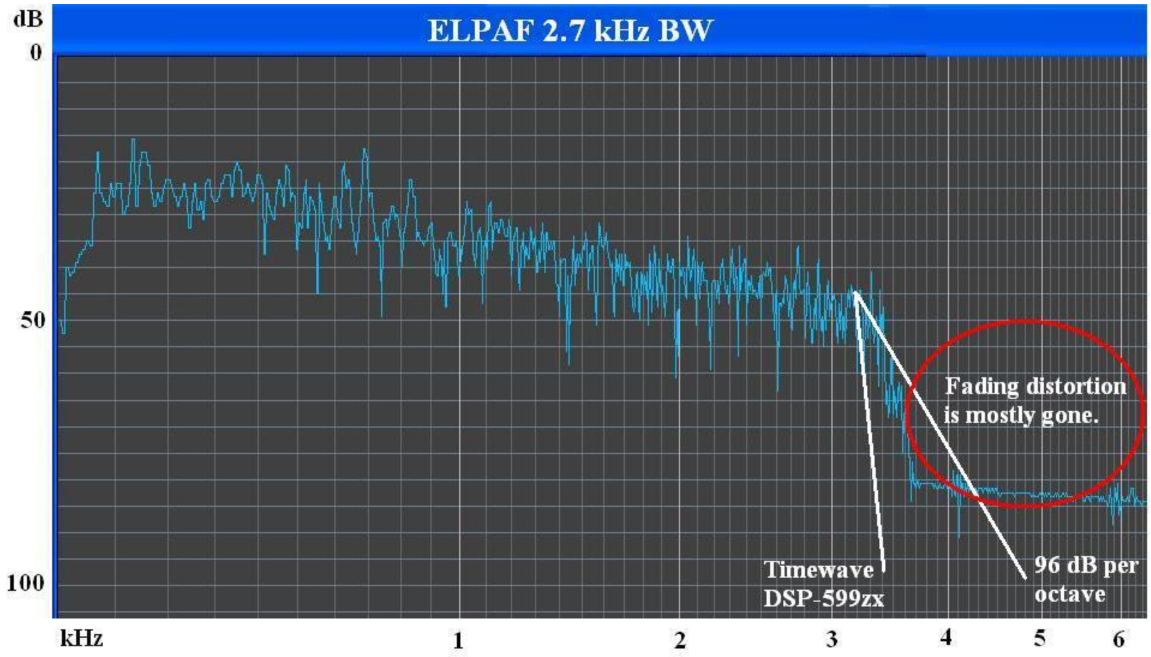
After considering possible kinds of audio filters, it seemed to me that elliptic filters, if the inductors and capacitors could be scaled to practical values, might provide the sufficiently sharp cutoff I wanted. Also, elliptic filter tables (in ARRL Radio Amateur's Handbooks) allowed me to easily determine component values for whatever cutoff frequencies I wanted, and to scale the values for 8 ohms. As it turned out, the component values for 2.7 kHz and 4.0 kHz cutoff frequency elliptic low pass filters were practical. The voltage for 2 watts into 8 ohms is 4 volts, so I used 50 volt non-polarize capacitors for greater power handling capability. The current for 2 watts into 8 ohms is 500 mA, but I could not find any high Q and suitably high current off-the-shelf inductors. So I wound the inductors on Amidon FT-82-61 toroids (u = 125) using #24 enameled copper wire. Because there is no formula for calculating the number of turns for multilayer toroids, the numbers of turns were found by trial and error using an AADE inductance meter (L/C Meter IIB; www.aade.com). I used between 2 and 3 (close wound on the inside circumference) layers of #24 enameled copper wire, about 95 turns for 740 uH and about 89 turns for 640 uH. Between 5 and 6 feet of #24 wire was used for each inductor, which provided excess wire (better too much than not enough). For 410 uH and 330 uH the turns were 72 and 65 respectively. The 8 ohm resistor at the output (which is switched by the 1/4 inch plug) provides the necessary 8 ohms filter termination when a speaker is not used. The switched resistors in the headphones line are for high and low impedance headphones. The filter input must be connected to the 8 ohms speaker output of the receiver; otherwise the filter performance will be degraded.

An audio spectrum analyzer was used to examine the shape factors of the elliptic low pass audio filters and to study the nature of fading distortion. The best audio spectrum analyzer I found for these purposes was WavePad; see www.nch.com.au/wavepad . Two "snapshots" of the WavePad spectrum display are given below. The receiver used for these measurements was an R390A with a (modified) 6 kHz BW and FAST AGC.

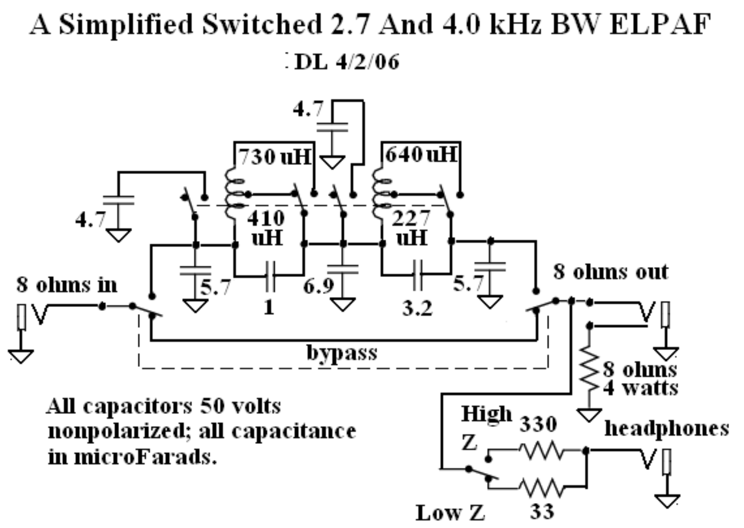
The first spectrum snapshot below, without filtering, shows where most of the fading distortion occurs, namely in the frequency range above about 3500 Hz.



The second spectrum snapshot below shows the audio typically obtained with the 2.7 kHz BW elliptic low pass audio filter. The rolloff of the 2.7 kHz BW elliptic filter appears to be better than 96 dB per octave, but not as good as the Timewave DSP-599zx (which is indicated on the snapshot). Also, the stopband of the 2.7 kHz elliptic filter is not nearly as deep as the Timewave DSP-599zx. But based on performance, the the elliptic filter stopband, both in the 2.7 and 4.0 BW's is more than adequate; cf. the comparisons with AM synchronous detectors below.



Winding four toroids with between 65 and 96 turns of #24 enameled copper wire is quite tedious. So I thought about how I could implement the 2.7 and 4.0 kHz BW filters using only two toroids with taps. As it turned out it can easily be done in an obvious manner (using two tapped toroids, and switching capacitors) with the with a 6 pole double throw toggle switch. But I could find none in my catalogs. A high quality 6 pole double throw rotary switch is available for about $30, Electroswitch part # D4G0603N (Mouser 690-D4G0603N), so the switched filter can be implemented that way. By taking some minor liberties with the filters designs, a 4 pole double throw toggle switch can be used. I used Allied Electronics 676-3280 large lever C&K toggle switches, about $16, rated at 100,000 make and break cycles. The bypass shown in the schematic at left is optional. Because there is no 5th toggle switch position, the 2.2 and 3.2 mF capacitors cannot be switched for the simplified filter; so the 330 uH inductor was decreased to 227 uH (about 55 turns) to give the same resonant frequency



for that parallel LC. And because there is no 6th toggle switch position, the output capacitor cannot be switched for the simplified filter; so the intermediate value of 5.7 mF was used in place of switching 4.7 mF and 6.9 mF.

I have been using an elliptic low pass audio filter with switched 2.7 and 4.0 kHz BW's for almost a year now and have compared it with many AM synchronous detectors on numerous cases of fading and other distortion. All of the comparisons were made with the receivers set for FAST AGC release so that the AM synchronous detectors would have the maximum potential for improving recovered audio. The ELPAF 4.0 kHz BW reduced fading distortion much more than the AM synchronous detectors used in the Racal receivers RA6790, RA6793(A), and RA6830, in the NRD-525 receiver, and the external AMSD-2. In fact, the AM synchronous detectors in those receivers and in AMSD-2 reduced fading distortion very little, if any. The ELPAF 4.0 kHz BW reduced fading distortion about the same as the AM synchronous used in the Drake R8B and the Watkins Johnson WJ-8711A (the mil version of the HF-1000A). Both the R8B and the WJ-8711A (HF-1000A) appear to have some audio filtering built in, and I have found no way to defeat that built in audio filtering. So the comparison of those AM synchronus detectors to the 4.0 kHz BW ELPAF was not a fair comparison, with the unfair advantage going to the R8B and WJ-8711A (HF-1000A). The ELPAF 2.7 kHz BW reduced fading and other forms of distortion as much as or more than the R8B and WJ-8711A (HF-1000A) in tough AM DX situations, such as for MW splits, for nighttime MW graveyard channels, and for foreign MW signals on domestic frequencies with domestics deeply phased.

Of course, ELPAF never growls or otherwise loses lock because it is not an AM synchronous detector. And, of course, the receiver with which ELPAF is used can be tuned so that either the upper or lower sideband of the AM signal (or any contiguous segment of the AM signal containing the AM carrier) is selected (to minimize adjacent imterference), which is not possible with the WJ-8711A (or HF-1000A). ELPAF was not designed as an accessory for program listening, but rather for DXing. Nevertheless, the 4.0 kHz BW has quite good fidelity and is as good as or better than most, if not all, AM synchronous detectors for program listening.