

THE 1030/1090 NOTCH FILTER STORY ---A FAMILY HISTORY!

“In the Beginning.....”.....there was a need! Systems utilizing the spectrum between 960 and 1215 MHz overlap the 1023-1037 and 1083-1097 MHz frequency ranges used for navigation. All of the systems involved are designed to prevent radiation of energy in the navigation bands, but a malfunction might accidentally results in some emission and a consequent navigation error...a big problem if flying at 1000 MPH near a mountain (or another aircraft)! In the commercial world “turn off your laptops and other portable electronic devices” is a familiar instruction. However, it is not so easy to implement the same function in military spread spectrum communication systems, such as JTIDS, MIDS or other Link-16 applications.

System designers have chosen to use a “fail-safe” method of preventing incidental or accidental radiation in the “forbidden” bands: the use of an in-line notch filter providing significant rejection of energy in the two navigation bands while simultaneously minimizing any passband effects. These notch filters display low insertion loss and low group delay distortion in the passbands, i.e. the non-rejected bands. In most cases, the notch filters are combined with a bandpass or lowpass filter that acts to suppress any harmonic energy generated within the high-power portion of the system. In some cases, the notch filters are combined with circulators to provide a duplexing function (interconnect antenna, receiver and transmitter), or with switches to provide the ability to “bypass” the notch filter, if desired. The use of an integrated bandpass or lowpass filter is required if a circulator or solid-state switch is incorporated. The circulator acts in a slightly non-linear fashion, generating harmonic and noise energy, while the switch acts far more non-linearly....both situations are improved dramatically using the incorporated bandpass filter.

Figure 1 shows the earliest member of the family....the 61351B Notch Filter Assembly, used in Naval applications. This filter operates in the JTIDS system, at 1500 W peak power, 600 W average power, and with more than 60 dB rejection in the 1030/1090 MHz bands. The integrated bandpass filter provides harmonic rejection up to 9 GHz. The circulator provides the duplexing function described previously. This little beauty weighs in at about 44 lbs!

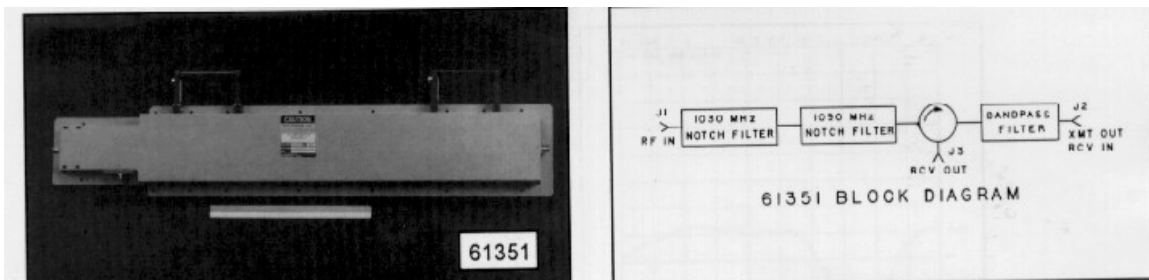


FIGURE 1
61351B NOTCH FILTER ASSEMBLY

The design approach taken to the notch filter is an air-slab line cascade of two Chebychev (N=5 and N=7) parallel-coupled bandstop filters [1]. The design is quite conventional, excepting the very high power capability and extreme temperature stability resulting from the design and placement of the tuning elements. The NFA operates over a temperature range of -30 to $+65$ C.

For packaging reasons, it has been found possible to provide a similar cascade of filters, with each of the filters “folded” in the middle. This approach was taken with the notch filters used in another NFA, P/N 83521B.

A view of that assembly is shown in Figure 2.

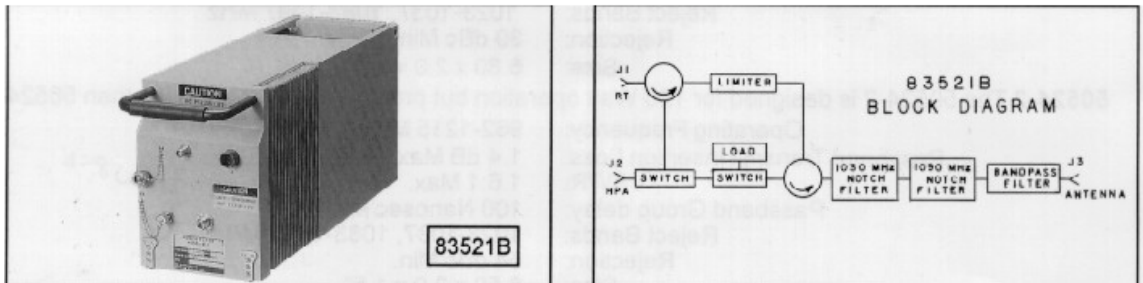


FIGURE 2
83521B (“MCE” NFA)

The folded notch filters (still Chebychev, i.e. ladder network) are shown in Figure 3. Except for folding, the filter designs are similar to the in-line 61351B....also weighs in at over 40 lbs.



FIGURE 3
FOLDED NOTCH FILTERS

The need for greater selectivity evolved a modified approach to implementation of such folded filters. The approach is derived from the seminal paper [2], and has been described fully in [3], as well as in earlier technical articles on quasi-elliptic notch filters

for AMPS/GSM separation, on this website. In essence, finite frequency transmission zeros are implemented by the choice of main-line impedance steps within these generalized notch networks. The filters thus provide “elliptic” responses, with sharp attenuation skirts combined with the widest possible passband.

By now it is clear that these very low loss and high performance filters are large! For airborne fighter applications, some smaller approach was required. In [4], a transformation was employed converting the parallel-coupled transmission line circuit into one in which short circuited stubs are capacitively coupled to a 50 ohm main line. The network, combined with some innovative design for the short-circuits and a proprietary series coupling capacitance method, enabled implementation of rather compact, Chebychev-response notch filters. The approach, illustrated in Figure 4, allowed for both in-line and folded approaches. Two such filters (one tuned for the 1030 band, the other for the 1090 band) were combined with a bandpass filter to provide the standard system required dual notch filter....RS P/N 22761-2F....which has been used in many Link-16 applications as a requirement for receiving a license from the FCC

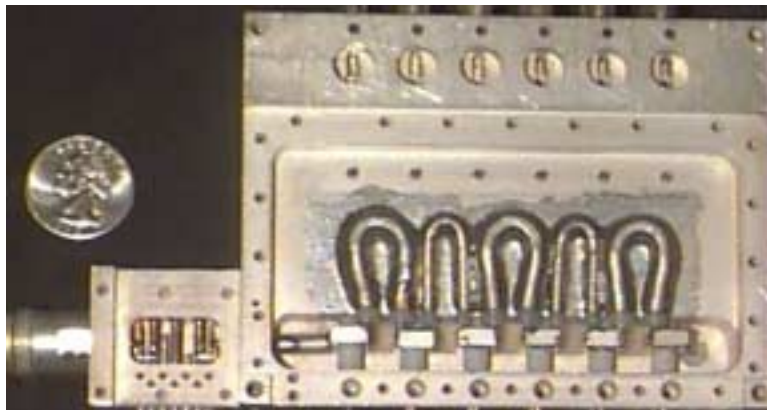


FIGURE 4
22761-2F-ORIGINAL CHEBYCHEV DESIGN

Reflection on the nature of this coaxial design has led to a new circuit [5]. Actually, this circuit is the coaxial implementation of the generalized notch filters described in the article on this website referred to earlier....”Quasi-Elliptic Notches for AMPS/GSM separation”. The series coaxial sections are replaced by L-C networks providing the impedances and phase lengths required by a quasi-elliptic synthesis (see Figure 5). The resulting filters display sharper attenuation skirt, wider passbands and better temperature stability than the original coaxial designs. The approach has been implemented in the standard 22761-2F dual notch, and thus all newer units display better specifications (about 0.25 dB lower insertion loss in the passbands) than the original design. This approach has also been implemented in both 1030 and 1030/1090 dual notch designs for airborne fighter applications. The designs have been tested at 800W peak, 200 watts average power, at up to an 80,000 foot altitude. These filters have also been combined with solid-state switches to enable bypassing the notches when it is desired to transmit in the 1030 and/or 1090 MHz bands. The combined switch-filters have been tested at 300W

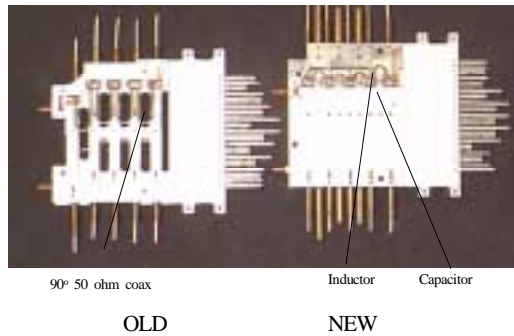


FIGURE 5
Coaxial and L-C Notch filter designs [5]

peak, 125 W average power, at up to an 80,000 foot altitude. A photograph of the 1030 MHz versions of these filters are shown in Figure 6, RS P/N 63531A-1A (switched) and 63531A-2A (non-switched). The switched filter is also provided with a power supply and logic driver, as a fully-integrated subsystem.

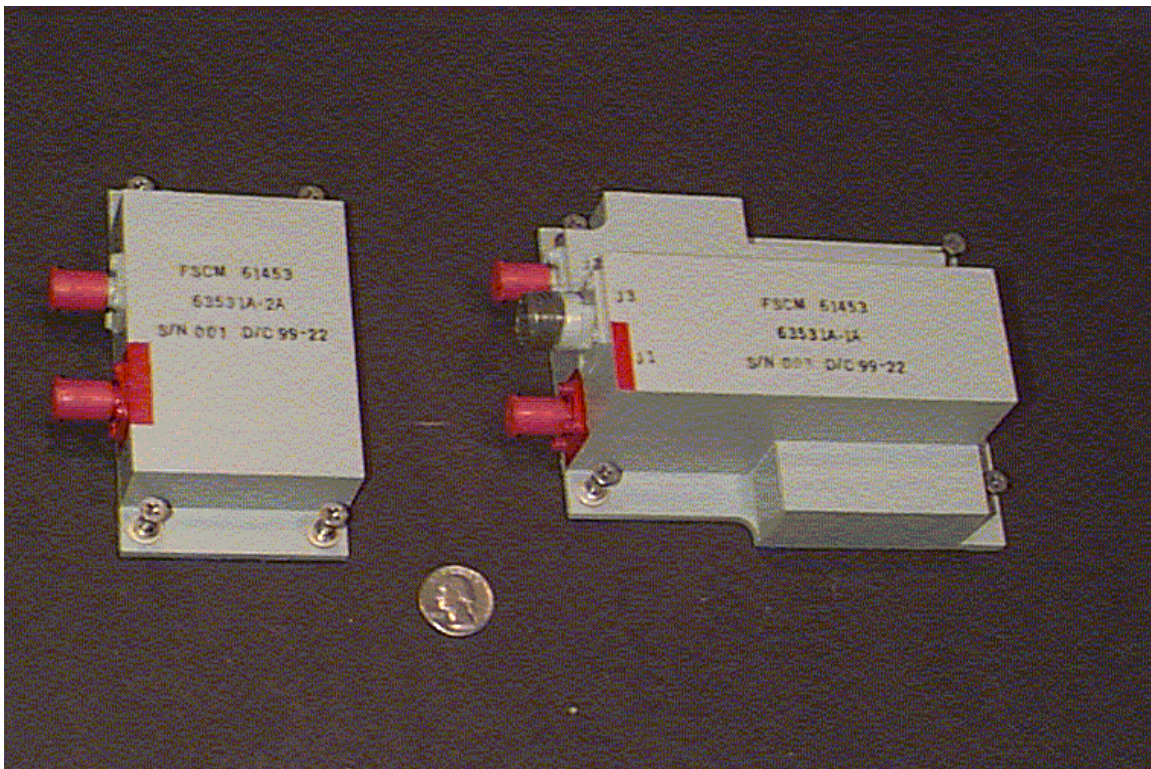


FIGURE 6
1030 MHz SWITCHED AND FIXED HIGH-POWER NOTCH FILTERS

Table 1 is a summary of the properties of the various notch filter “generations”....stay tuned for more developments in the near future!

Approach	Power Loss	Response	Rejection	Size
Air-slab Chebychev	1.5KW very low	Chebychev	very high	Large, heavy In-line or folded
Air-slab Quasi-Elliptic	1.5KW even lower	quasi-elliptic (steeper slope)	gets to high value quickly	30% smaller also folded
coaxial Chebychev	0.5 KW 3x airslab	Chebychev	60 dB or so	1/4 airslab
coaxial quasi-elliptic	0.5 KW 2.5xairslab	quasi-elliptic	50 to 60 dB	1/4airslab

Notes: The air-slab designs are suitable for ground or naval applications, while the coaxial designs are optimized for rough-environment airborne situations

TABLE 1
PROPERTIES OF THE AVAILABLE 1030/1090 NOTCH DESIGNS

REFERENCES

1. **B. M. Schiffman and G. L. Matthaei, “Exact Design of Band-Stop Microwave Filters”, IEEE MTT Trans. MTT-S, January, 1964**
2. **J.D. Rhodes, “Waveguide Bandstop Elliptic Function Filters”, IEEE Transactions MTT-S, MTT-20, November 1972.**
3. **R. V. Snyder, “Recent Advances in the Implementation of Quasi –Optimum Filters”, Proc. European Microwave Conference, Amsterdam, 1998**
4. **R.V.Snyder, “A Compact, High Power Notch Filter with Adjustable F_0 and Bandwidth”, IEEE Transactions MTT-S, July, 1994**
5. **R. V. Snyder, “Quasi-Ellptic Compact Notch Filters Using a Mixed Lumped and Distributed Circuit”, IEEE Trans MTT-S, April, 1999**