TELEDYNE
DEFENCE & SPACE
Everywhereyoulook™

TELEDYNE WHITE PAPER

De-Confliction Filtering in Communication Systems

A White Paper from Teledyne Defence & Space | teledynedefence.co.uk

Electro-mechanically tuned high power UHF bandpass filter.

I. Introduction

The dense signal environment in which radio communication systems work becomes even more challenging with the shift to higher capacity links needing wider bandwidth in which to operate. Signal spreading caused by intermodulation in the transmitter and receiver requires either extremely linear devices or suitable filtering to avoid interference. The situation becomes most severe where countermeasures are deployed that risk, as a minimum, reducing system dynamic range.

Transmit filtering is used to mitigate the effects of harmonics, broadband noise and intermodulation distortion but the number of possible channels and the passband width of each requires a tunable filter to meet flexibililty requirements.

One such environment is that experienced by tactical communication systems operating in the 200-450MHz frequency range. Radios operating in this band can generate harmonics, broadband noise and intermodulation distortion that could interfere with other systems at adjacent frequencies. Transmit filtering is used to mitigate these effects, but the number of possible channels and the passband width of each requires a tuneable filter to meet the flexibility required.

In addition, there are likely to be countermeasure systems present that fill the spectrum with wideband signals to prevent unwanted communications. Leaving ‘windows’ in the transmitted output of these systems that coincides with the receive bands of the radios is relatively straightforward to generate with high dynamic range DACs. The final power amplifier can also be operated in a relatively linear mode where the output power is ‘backed-off’ from saturation. The width of these systems however generates intermodulation that falls in the very sensitive receive band of the radio system. A tuneable bandstop filter that tracks the operational channel of the radio, very effectively clears this window of transmit noise.

Modern tactical radios employ frequency hopping techniques to avoid interception. The filtering solution is thus required to follow the radio and re-tune within ~15-20us. This requirement along with the high transmit power of both the radio and countermeasures present the greatest challenge.

II. Fast Switching Electronically Tuned FIlters

Tuneable bandpass and bandstop filters in the UHF band are widely available - indeed Teledyne Defence produces tuneable filters across a range of applications and frequency ranges. The limiting factors are generally power handling and Q factor, restricted by the availability of a tuning device that has simultaneously a wide tuning range, high voltage operation and low loss. Various elements are used including PIN diode switches and varactors, MEMs devices and para-electric and magnetic material structures. To date, Teledyne is unaware of any materials what are able to satisfy all these requirements.

An alternative configuration is described that provides optimised RF filter performance with a compromise between tuning speed and channel flexibility.

III. Configurable Filters

Filter insertion loss for systems operating at high output powers is clearly critical in maximising transmit/receive power levels and minimising DC consumption. Mechanically tuned filters currently are able to offer the lowest loss and narrowest filter bandwidths – close to those of similarly sized fixed frequency filters. Teledyne Defence has designed filters that tune mechanically under electronic control, operating in the 200-450MHz band.

A system comprising a set of such filters can be configured to allow a number of channels to be switched via high speed electronic switches to suit the operation of a frequency hopping radio albeit constrained by the number of filters deployed as illustrated in Figure 1. Each filter is set to a pre-determined radio channel with fast electronic switching between filters. The filters can then be re-tuned to a different set of channels for the next mission.

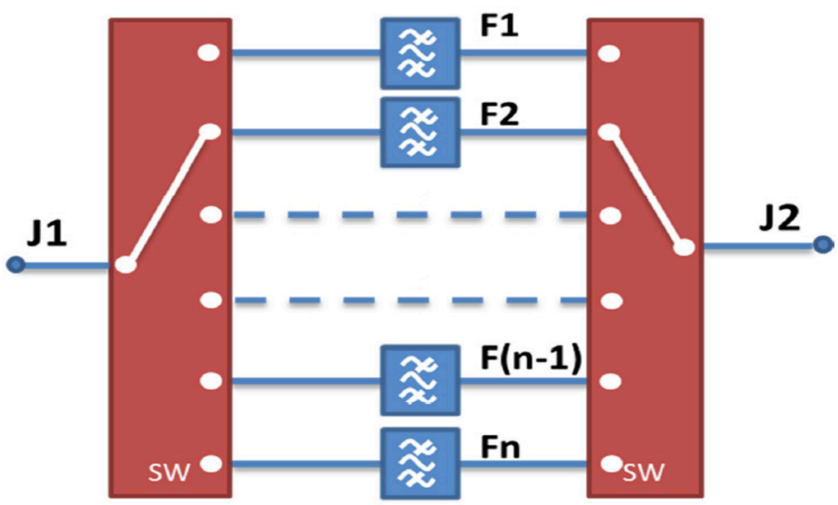

Figure 1. Set of ‘n’ electro-mechanically tuned filters in addition to fast electronic switching between filters

Alternatively, a redundant channel (or channels) can be included that is dynamically re-tuned taking approximately 1s to re-tune anywhere within the operational bandwidth (Figure 2). Channel selection of one of the 'n' available channels is via fast electronic PIN switches. The redundant channel(s) is re-tuned and then made available to be included in the channel plan whilst another of the filters is re-tuned.

Whilst this does not offer full instantaneous channel coverage, all channels can be accessed whilst the system is operational.

This methodology can be used for both bandstop and bandpass filters.

The number of filters is practically constrained mainly by size – multiway switches can be readily implemented for either the bandpass or bandstop configurations. Additionally, bandstop filters can be connected in series with bypass switches around each filter to bypass the filter – with a consequent increase in insertion loss.

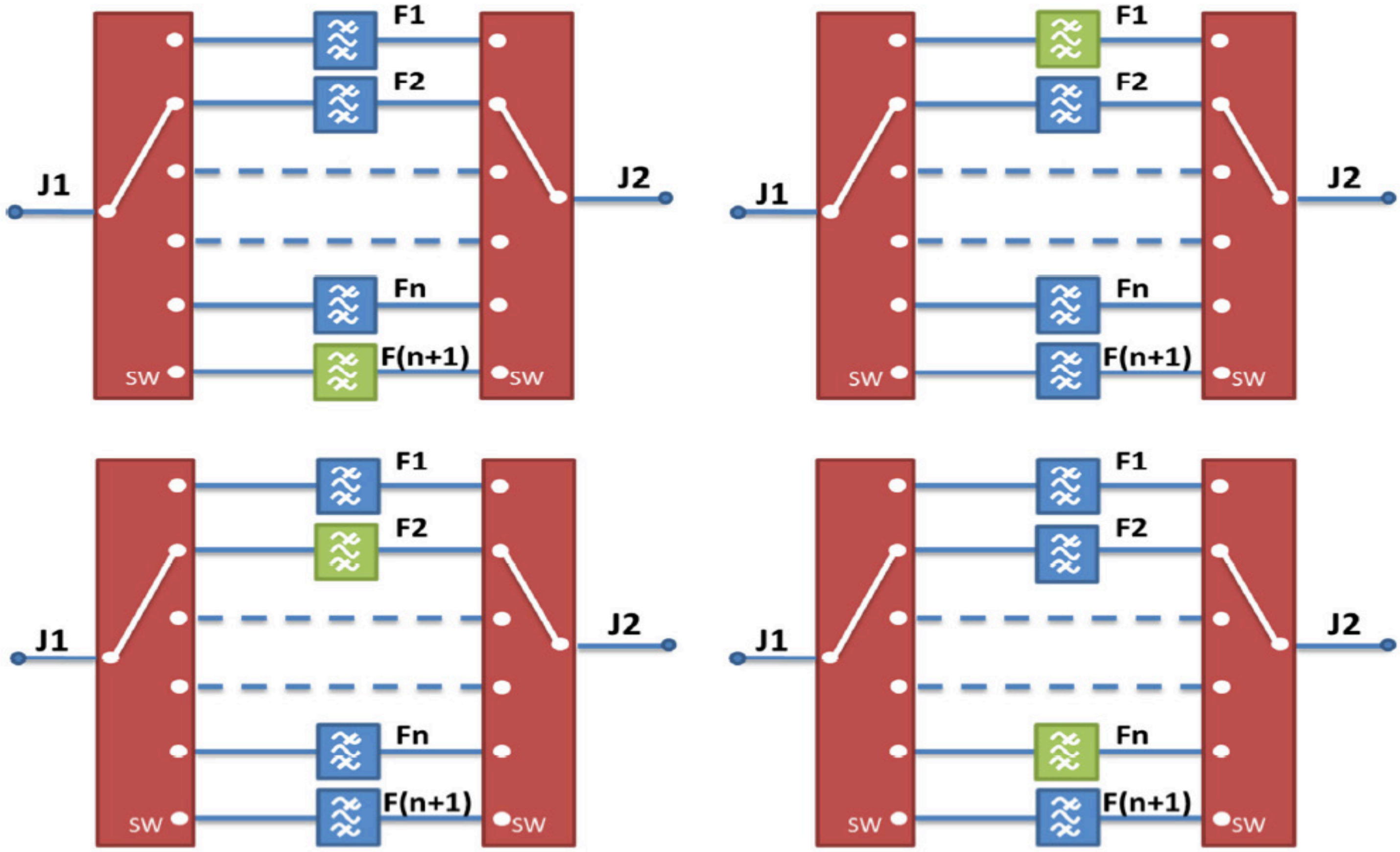

Figure 2. Electronic switches route signals through filters. Redundant filter (coloured green) is re-tuned in a programmed sequence keeping 'n' filters (blue) instantaneously active.

IV. Filter Performance

Combline filter structures integrate well with an electromechanically tuned filter and provide the lowest insertion loss structures. The tuneable bandpass structure used in TD products has constant bandwidth over the full tuning range so that whilst the insertion loss of the resonators is lowest at the low end of the band, the wider % bandwidth offsets this loss giving a fixed insertion loss over the full tuning bandwidth. The insertion loss of a 4th degree filter with 30dB rejection at 1.8% away from band centre and 45dB rejection at 3.4% from band centre is typically 1.7dB including the losses of the electronic switches and handles >47dBm of RF power. Figure 3 shows a single channel filter of this type.

High power combline structures are also the optimum technology for tuneable bandstop filters where high Q and high power handling are again paramount. Typically, a filter with a 75dB notch of 2MHz bandwidth has 2dB insertion loss in the passband. The stopband insertion loss returns to within 2dB of the passband loss within +/12MHz of the notch centre.

A significant proportion of this loss is due to the matching circuits required to provide a match in the stopband of the filter. Allowing the filter to reflect power from the stopband region improves the passband insertion loss significantly – typically by 0.5dB. In both cases power handling is >53dBm in the passband and >49dBm in the stopband.

	Insertion Loss / Bandwidth	Power Handling	Tuning speed / flexbility
Electronically Tuned	typically 2.5dB IL / 140MHz 30dB rej. (Q limited to ~50)	<50W	<15us
Electro- mechanically Tuned	typically 1.7dB IL / 8.1MHz 30dB rej. (Q proportional to size >1000 typical)	>100W	<15us between filters in a set. Filters can be re-tuned in ~1s.

Table 1 highlights the key performance differentiators.

Conclusion

Dynamically re-configurable filters for de-confliction of signals in the UHF band have been presented having low insertion loss and high power handling characteristics. The tuning technique offered is a practical compromise between switching speed and filter performance. Q factors of >20 times that of electronically tuned filters result in narrow, low loss bandpass structures that can handle more than twice the RF power.

Teledyne Defence & Space
Airedale House, Acorn Park
Shipley, West Yorkshire, BD17 7SW, UK
www.teledynedefence.co.uk
Tel: +44 (0) 1274 531602
Fax: +44 (0) 1274 595724
salestds@teledyne.com