National Centre for Radio Astrophysics

Internal Technical Report

GMRT/OFC/April 2015

Notch Filters

&

Switchable Notch Filter Bank

For RFI Mitigation

Revision	Date	Modification / Changes
Ver. 1.0	22 April 2015	Final Version

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We thank **Prof. Yashwant Gupta.** *Dean of GMRT,* for making it possible to work on this assignment and giving constant encouragement with his valuable comments.

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Content

1) Introduction :

Switchable Notch Filter Bank is intended to use in Giant Metrewave Radio Telescope(GMRT) to eliminate the Radio Frequency Interference (RFI) lying in different observation Band of Radio Astronomy. As by international agreement, radio frequencies are divided up into blocks, or bands, designated for different types of uses for example; **AM radio** , **FM stations**, **TV stations**, **wireless two-way radios** , **Mobile communication.** However, transmitters using frequencies near those assigned to radio astronomy can cause interference to radio telescopes. Wideband receivers of upgraded GMRT receiver have high dynamic range to co-exist with the strong commercial trasmission lines but down the chain with large gain, the dynamic range of receiver gets limited. Including notch filters at appropriate locations in the receiver help in regaining the dyanmic range of the receiver. Some of the interference are not present when GMRT switches to different sub-band and some interferences appear occationaly and not present always. Hence having notch filters always in the receiver chain is not desired. The objective of this paper is to build a switchable notch filter bank which can be brought in the chain when ever needed and removed form the receiver when not in use. In addition this design helps in having certain filters that can be switched in cascade to remove interference from two different interference sources but in one single band of observation**.**

2) Block Diagram of Switchable Notch Filter Bank:

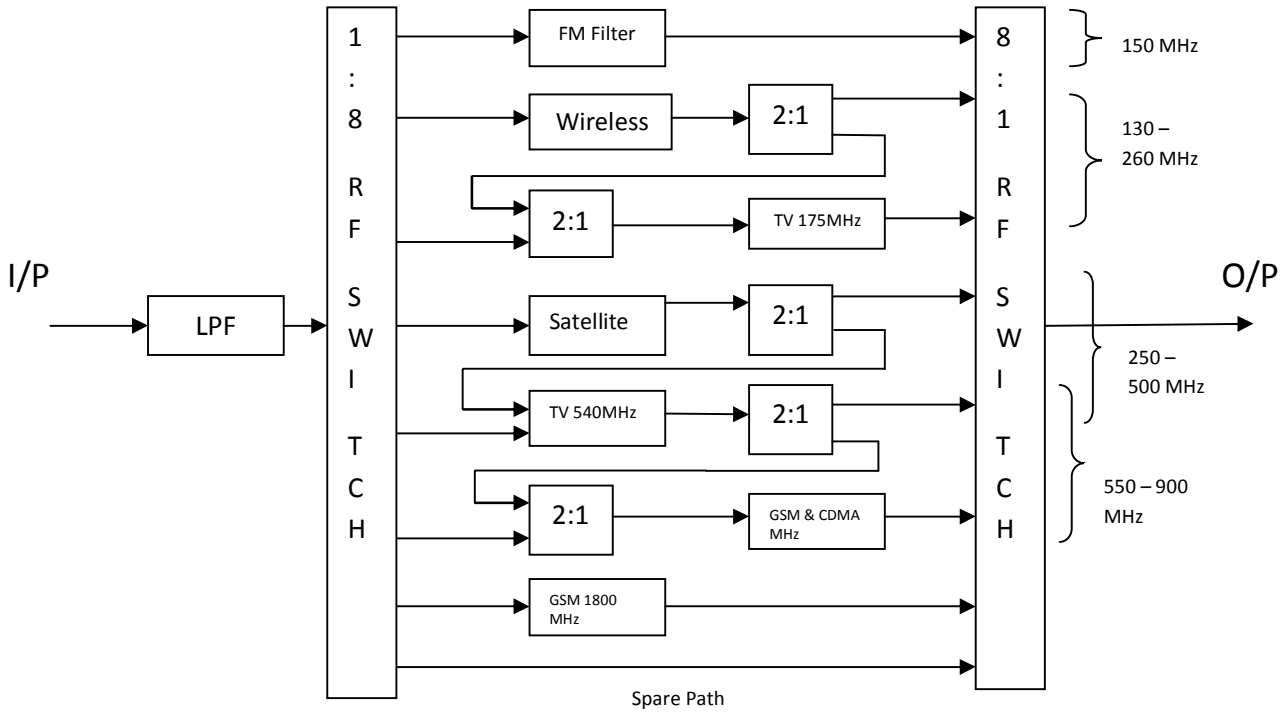


Fig.1 Block Diagram or Switchable Filter Bank

2.1) Filter used :

1) FM Filter
2) Police Wireless
3) TV 177 MHz
4) Satellite
5) TV 540 MHz
6) GSM 900 MHz
7) GSM 1800 MHz
8) Low Pass Filter

2.2) Switch used with Specification:

1) 2:1 RF Switch
2) 8:1 RF Switch

In both type of cofiguartion we are using MS3W- 50 DR+. Data sheet for the same is given at last page of this report.

2.3) Cable used:

1) Semi rigid cable
2) RG 214 flexible coaxial cable

Labjack Card was used for bit control

3) Filters In details:

What is the need of filters ??

Filters play important roles in many RF/Microwave Application. They are used to separate or combine different frequencies. The electromagnetic spectrum is limited and has to be shared , filter are used to select or confine the RF/Microwave signals within assigned spectral limits.

A filter allows signals through in what is termed the pass band. This is the band of frequencies below the cut off frequency for the filter.

3.1) RF filter frequencies

The cut off frequency of the filter is defined as the point at which the output level from the filter falls to 50% (-3 dB) of the in band level, assuming a constant input level. The cut off frequency is sometimes referred to as the half power or -3 dB frequency.

The stop band of the filter is essentially the band of frequencies that is rejected by the filter. It is taken as starting at the point where the filter reaches its required level of rejection.

3.2) Filter classifications

Filters can be designed to meet a variety of requirements. Although using the same basic circuit configurations, the circuit values differ when the circuit is designed to meet different criteria. In band ripple, fastest transition to the ultimate roll off, highest out of band rejection are some of the criteria that result in different circuit values. These different filters are given names, each one being optimised for a different element of performance. Three common types of filter are given below:

- ***Butterworth Filter:*** This type of filter provides the maximum in band flatness, although it provides a lower stop-band attenuation than a Chebyshev filter. However it is also able to provide better group delay performance, and hence lower overshoot.
- ***Bessel:*** This filter provides the optimum in-band phase response and therefore also provides the best step response. It is often used where signals incorporate square waves, etc as the shape is maintained best of all.

- ***Chebyshev:*** This filter provides fast roll off after the cut off frequency is reached. However this is at the expense of in band ripple. The more in band ripple that can be tolerated, the faster the roll off.
- ***Elliptic:*** This filter, also known as the Cauer filter has significant levels of in band and out of band ripple, and as expected the higher the degree of ripple that can be tolerated, the steeper it reaches its ultimate roll off.

3.3) Chebyshev filter basics

Some of the key features of the Chebyshev filter can be summarised as below:

- ***Roll-off:*** One of the main aspects of the Chebyshev filter is that it has a steep roll-off. It reaches its ultimate roll-off faster than other forms of filter. Accordingly is widely used in RF applications where a steep transition between pass-band and stop-band is required to remove unwanted products such as intermodulation of harmonics.
- ***Ripple:*** Although the Chebyshev filter provides a steep roll-off, this is at the cost of ripple. The in-band ripple of one type of Chebyshev filter prevents this format of filter being used in some applications where a flat in-band response is needed.
- ***Cut-off frequency:*** The common definition of the cut-off frequency of the point at which the response falls to -3 dB does not hold for Chebyshev filters in view of the way the filter rolls of faster than other types like the Butterworth filter.
- ***Chebyshev filter name:*** The name of the Chebyshev filter comes from the fact that the format and calculations for the filter are based on Chebyshev polynomials.

Chebyshev filter types

There are two types of Chebyshev filter that are available:

- ***Chebyshev type I filter:*** These are the most common Chebyshev filters. It has the steepest roll-off but exhibits in-band ripple.
- ***Chebyshev type II filter:*** The type 2 Chebyshev filter may also be known as the inverse Chebyshev. It is less commonly used than the Type 1 filter because it does not roll off as fast, and also requires more components. However, its big advantage is that it has no ripple in the pass-band, but does have what is termed equi-ripple in the stopband.

We have used Chebyshev type I filters for all Notch filters.

4) Notch Filters and Switchable Notch filter Bank Responses :

4.1) FM Notch filter :

As GMRT Antenna is efficient to observe 6 MHz to 3 GHz frequency band and we do observation in 50MHz and 150MHz**.** As Now a days there are lots of FM commercial channels are trasmitting their signal in 88 – 108 MHz Band which creates problem in 50 MHz and 150 MHz GMRT observation band. To supress this signal we are using FM Notch Filter.

It Supports up to 1 GHz of spectrum

Type: Lumped

Specs & Response:

Filter response on Network Analyzer:

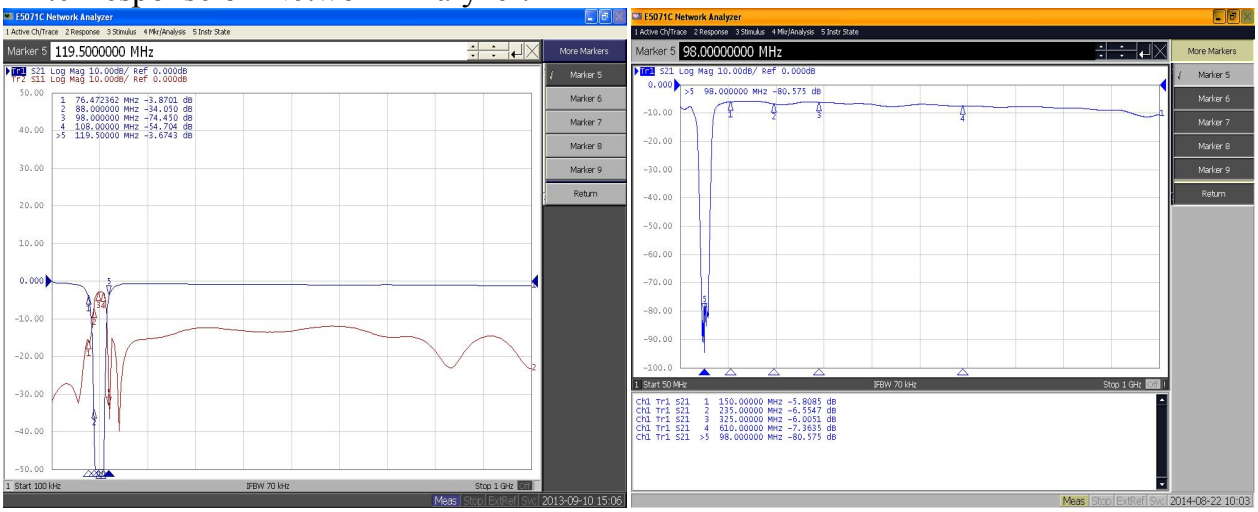


Fig. 2 (a) (b)

Fig2(a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Bandwidth	Lower 3 dB Cut Off Point	Higher 3 dB Cut Off Point	Return Loss	Insertion Loss
43 MHz	76 MHz	119 MHz	< -12 dB	Upto .23 dB @ 325 M .65dB @ 1 GHz >60 dB @ 98 M

When **Path 1** is activated, it shows the FM notch filter response in Switchable Notch Filter Bank.

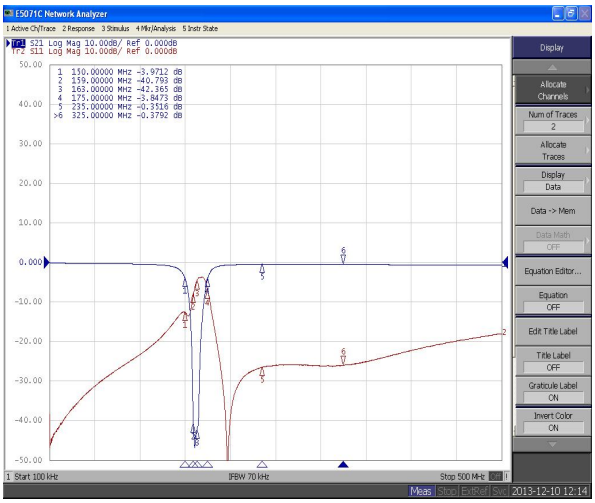
4.2) Police Wireless Notch Filter:

As Police wireless communiucation works on 159.20 Mhz, 163.20Mhz and 164 Mhz but it is not present every time. So we can't fix this filter into Front End box. GMRT operates at 150 MHz band and now uGMRT will operate 130-260MHz band. So to resolve this problem we are planning to have Police Wireless Notch Filter at receiver room.

Type: Lumped

Specs & Response:

Filter response on Network Analyzer:



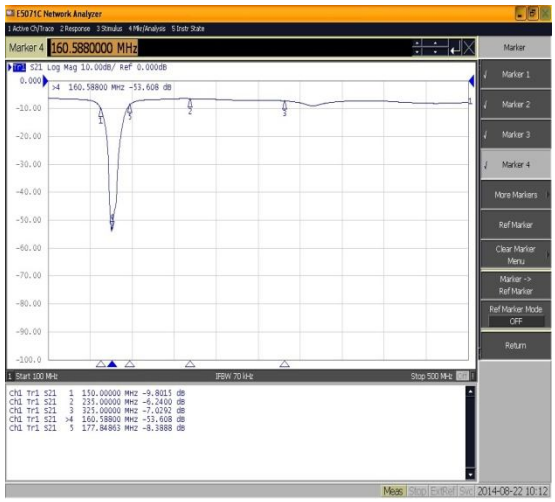


Fig. 3 (a) (b)

Fig1(a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Bandwidth	Lower 3 dB Cut Off Point	Lower 3 dB Cut Off Point	Return Loss	Insertion Loss
25 MHz	150 MHz	175 MHz	< -12 dB	Upto .23 dB @ 235 M .65dB @ 325 G >40 dB @ 149 M 163 M

4.3) 177 MHz TV Notch Filter :

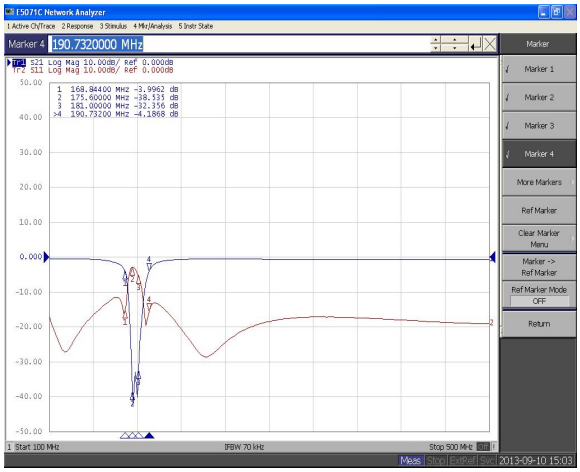
Doordarshan operates at 175.25 and 180.75 MHz and it creates problem for 160-230 and 235 MHz GMRT band.

Type: Lumped

Specs & Response:

This 177 MHz Tv Notch filter supports upto 500 MHz.

Filter response on Network Analyzer:



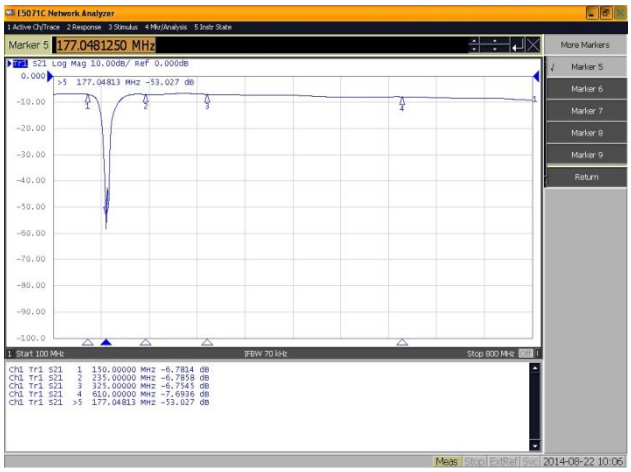


Fig. 4 (a) (b)

Fig1(a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Bandwidth	Lower 3 dB Cut Off Point	Lower 3 dB Cut Off Point	Return Loss	Insertion Loss
22 MHz	168 MHz	190 MHz	< -13 dB	Upto .3 dB @ 235 M .3dB @ 325 G >40dB @ 175 M

4.4) Combined Police Wireless Notch filter and TV175 MHz Notch filter Response in Switchable Notch filter Bank:

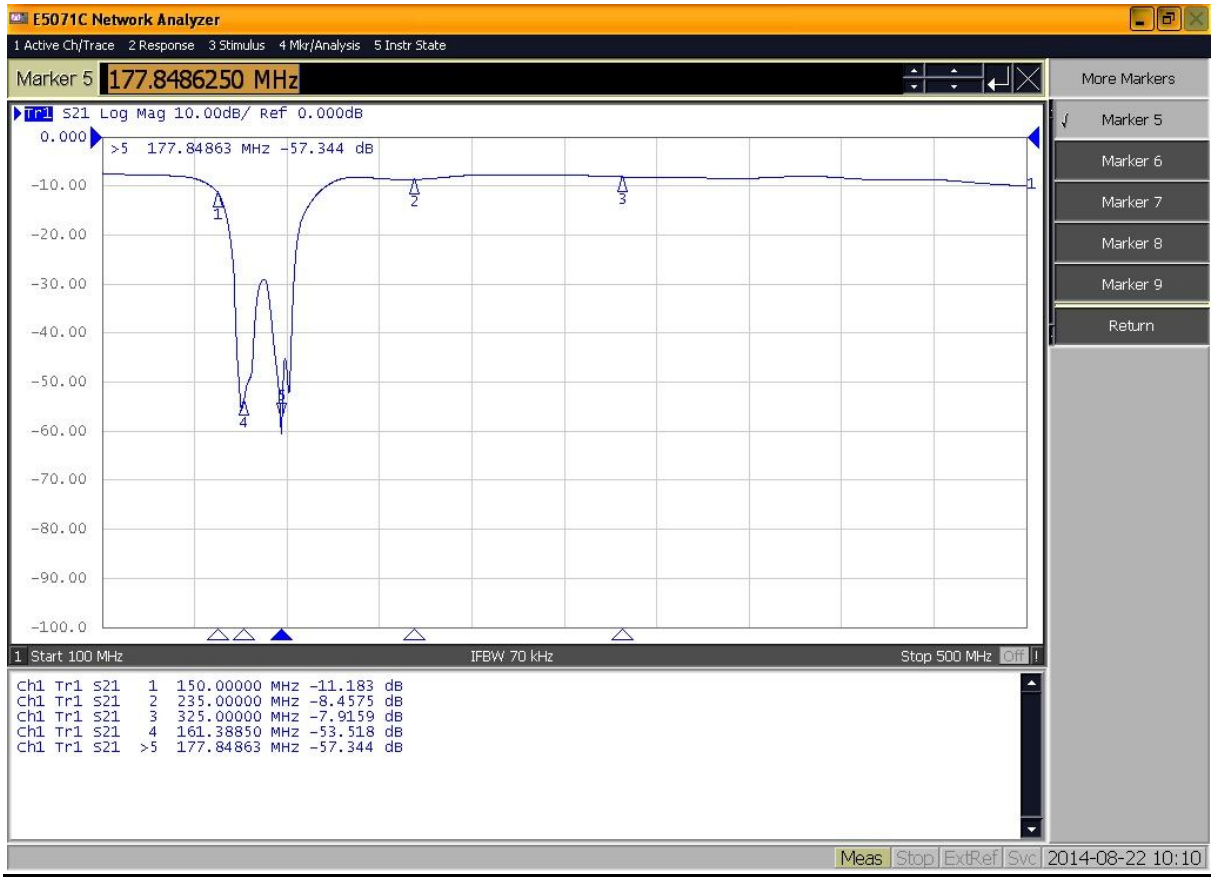


Fig5. Combined response

Both filters provides more than 40dBin cascaded manner and can be used wgen both RFI are present and it is useful for 130-260MHz GMRT observation band without affecting other GMRT observation bands.

4.5) Satellite Notch Filter :

Some military satellite operates in 235-270 MHz band and it creates problem for 160-230 and 250-500 MHz GMRT observation bands.

Type: Lumped
Support : Upto 1.5 GHz

Specs & Response:

Filter response on Network Analyzer:

Fig. 6 (a) (b)

Fig6(a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Bandwidth	Lower 3 dB Cut Off Point	Higher 3 dB Cut Off Point	Return Loss	Insertion Loss
48 MHz	230 MHz	278 MHz	< -15 dB	Upto .7dB @ 325 M .76dB @ 610 M 1 .06dB @ 1 G 1.5 dB @ 1.4 G >60 dB @ 245 M

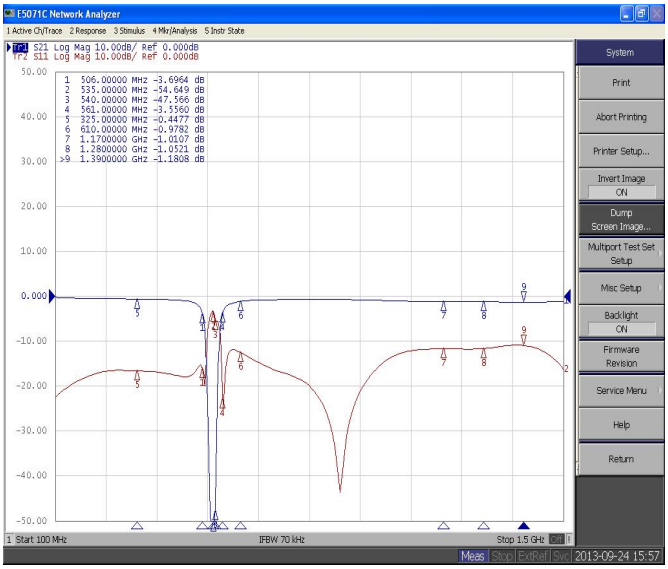
4.6) 540MHz TV Notch Notch Filter :

Doordarshan (DD2) operates at 535.25 and 541.25 MHz and it creates problem for 250-500 and 550-900 MHz GMRT observation band.

Type: Lumped
Support : Upto 1.5 GHz

Specs & Response:

Filter response on Network Analyzer:



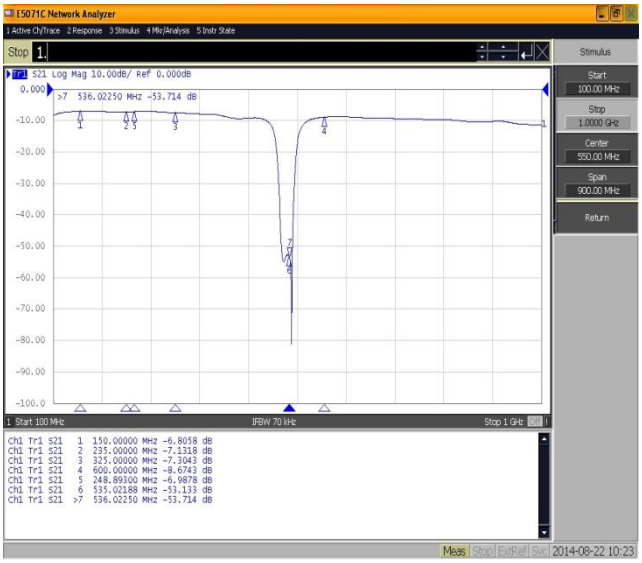


Fig. 7 (a) (b)

Fig7 (a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Bandwidth	Lower 3 dB Cut Off Point	Higher 3 dB Cut Off Point	Return Loss	Insertion Loss
54 MHz	506 MHz	560 MHz	< -12 dB	Upto .23 dB @ 325 M .65dB @ 1 GHz >50 dB @ 535M >50 dB @ 541M

4.7) Combined Satellite Notch filter and TV 540 MHz Notch filter Response in Switchable Notch filter Bank:

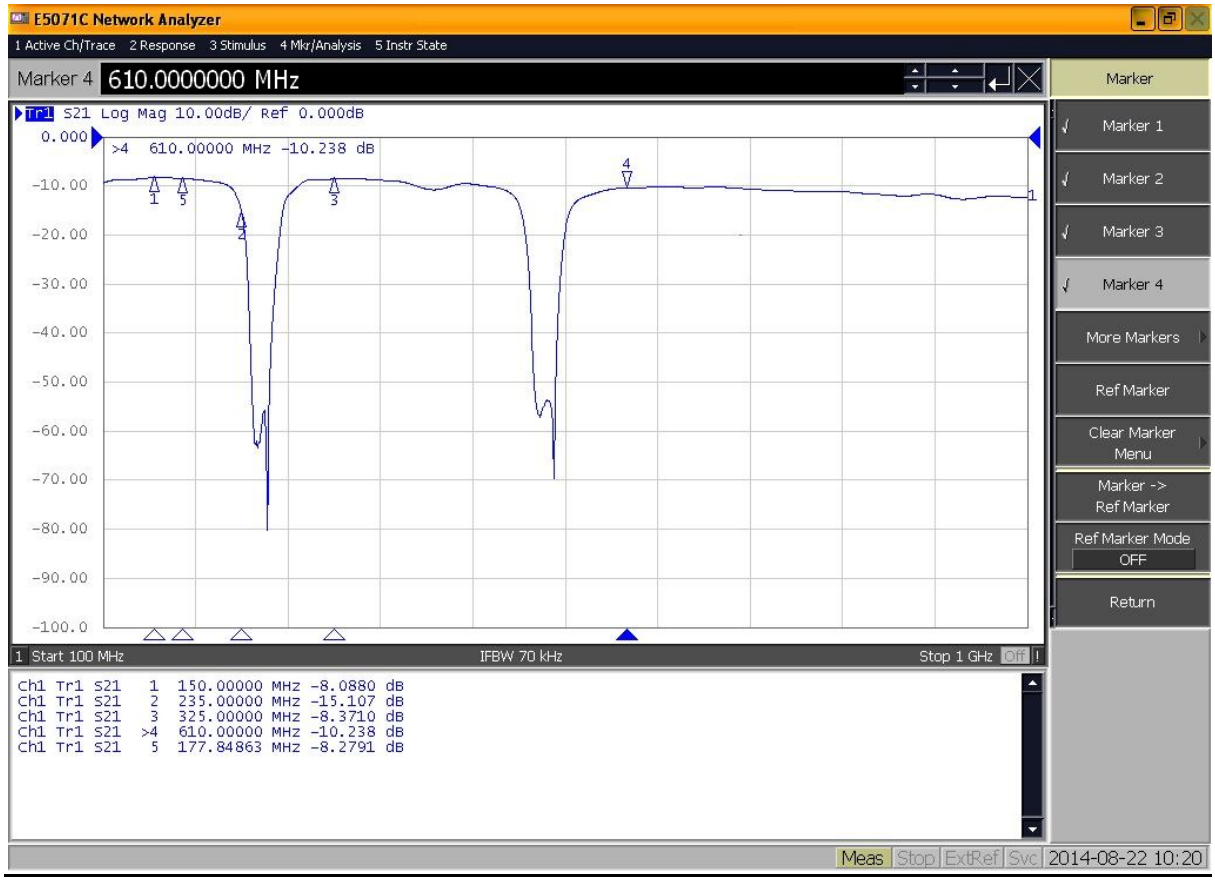


Fig 8. Combined response

Both filters provides more than 40dB in cascaded manner and can be used when both RFI are present and it is useful for 250-500MHz GMRT observation band without affecting other GMRT observation bands.

In Cascaded both filters insertion loss is about 1dB and gives very sharp band pass response for 250-500 MHz band.

4.8) GSM 900 MHz Mobile Notch filter:

Mobile operator in near by Area operates in GSM 900 MHz band which give problem in L- Band and 550-900 MHz band.

Type: Microstrip line (Parallel Coupled Lines structure)

Specs & Response:

Filter response on Network Analyzer:

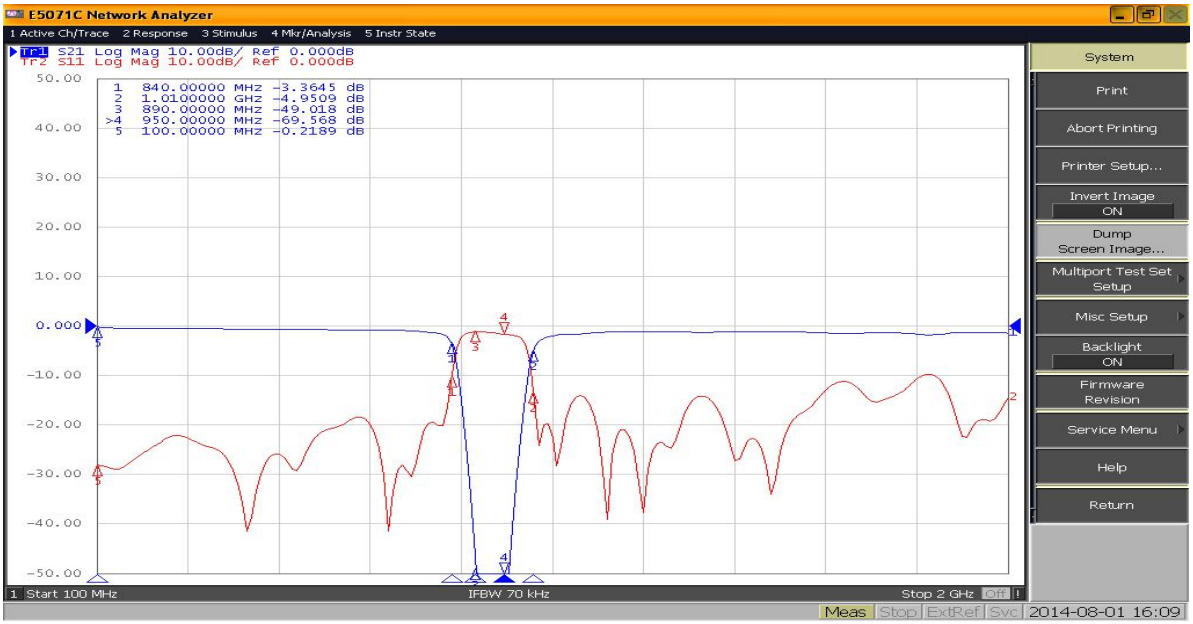


Fig 8. Combined response

3 dB Bandwidth	Lower 3 dB Cut Off Point	Lower 3 dB Cut Off Point	Return Loss	Insertion Loss
170 MHz	840 MHz	1010 MHz	< -18 dB	Upto .23 dB @ 325 M 1.4dB @ 1.3 G >60 dB @ 890 >60 dB @ 960

4.9) Combined TV 540 MHz Notch filter and GSM 900 MHz Response in Switchable Notch filter Bank:

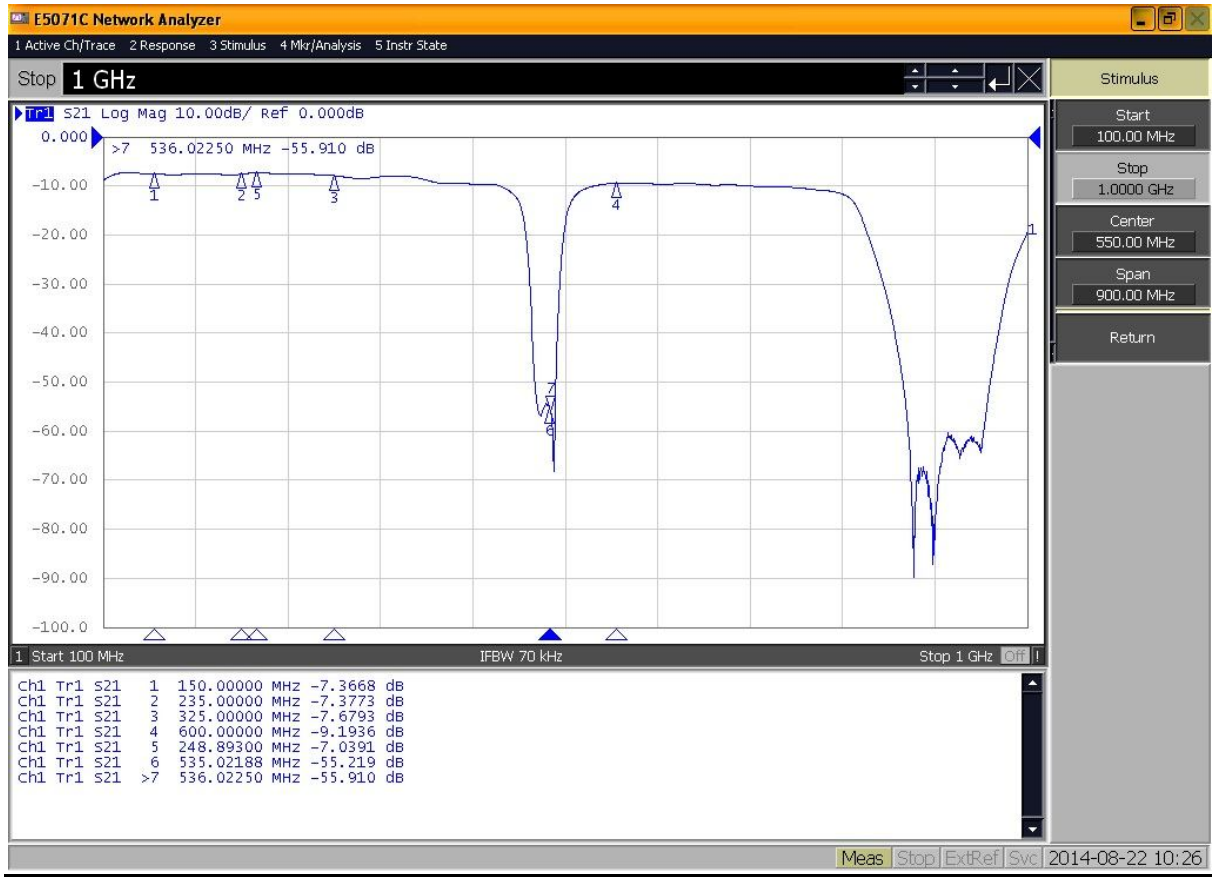


Fig 9. Combined response

Both filters provides more than 40dB in cascaded manner and can be used when both RFI are present and it is useful for 550-900 MHz GMRT observation band without affecting other GMRT observation bands.

In Cascaded both filters insertion loss is about 1dB and gives very sharp band pass response for 550-900 MHz band.

4.10) Low Pass Filter:

As GMRT operates upto 1420 MHz and so to suppress RFI above 1.5 GHz we and to reduce the image frequency this filter as a first stage of this Switchable notch filter bank scheme.

Type: Microstrip line (Stub line)

Specs & Response:

Filter response on Network Analyzer:

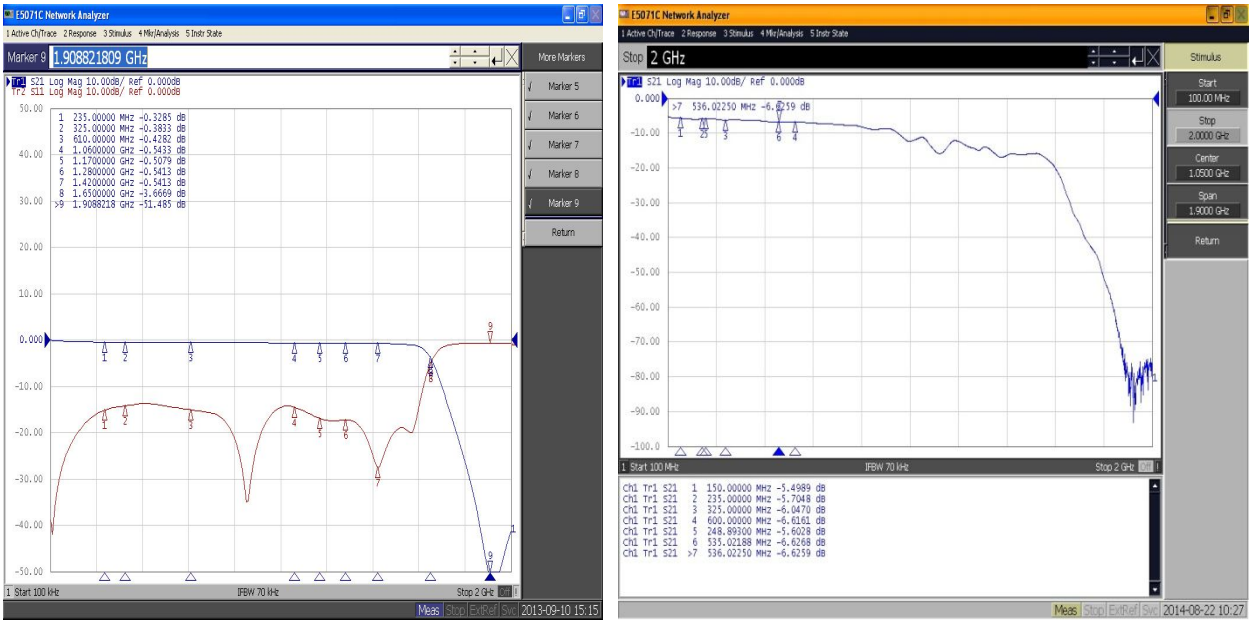


Fig. 10 (a) (b)

Fig10(a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Cut Off Point	Return Loss	Insertion Loss
1650 MHz	< -14 dB	Upto .43 dB @ 325 M .45 dB @ 610 M .60dB @ 1 GHz .23 dB @ 1.4 GHz >50 dB @ 1.85GHz

4.11) GSM 1800 MHz Mobile Notch filter:

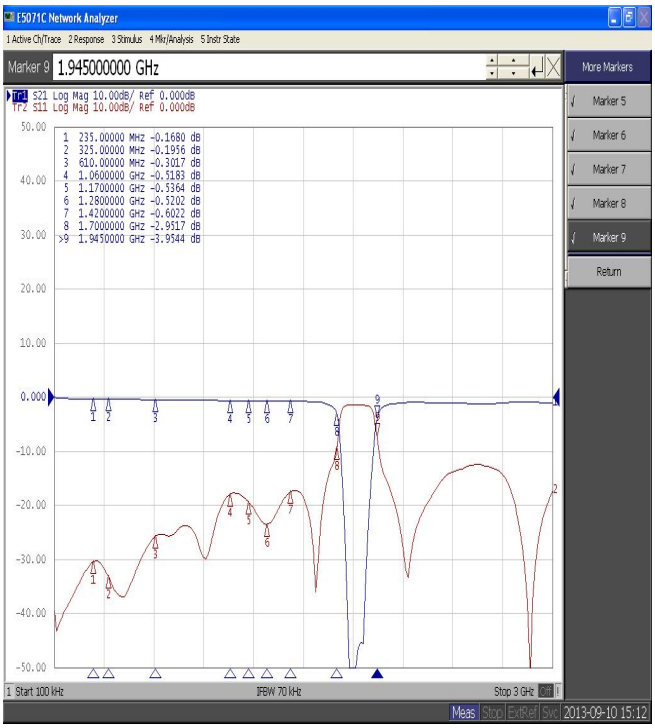
Some of Mobile operator in nearby area operates in GSM 900 MHz band .

This frequency is out of GMRT observation band but still to take care of this RFI we can use this notch filter in filter bank

Type: Microstrip line (Parallel Coupled lines)

Specs & Response:

Filter response on Network Analyzer:



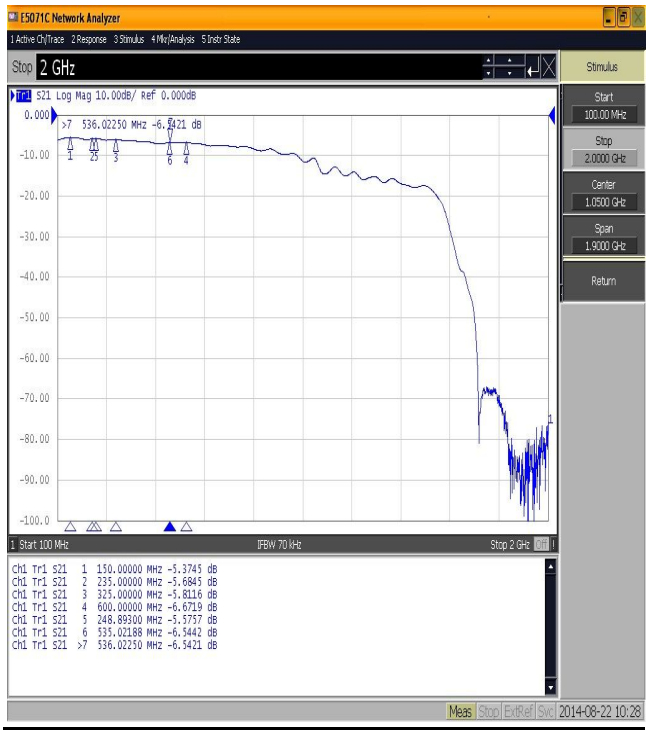


Fig. 11 (a) (b)

Fig11(a) : Filter Response on N/W Analyzer
(b) : Filter Response in Switchable Notch filter bank.

3 dB Bandwidth	Lower 3 dB Cut Off Point	Lower 3 dB Cut Off Point	Return Loss	Insertion Loss
145 MHz	1700 MHz	1945MHz	< -18 dB	Upto .1 dB @ 235 M .1 dB @ 325 M .3 dB @ 610 M .5 dB @ 1060 M .6 dB @ 1420 M >40 dB @ 1800 M

4.12) By Pass Mode:

If there is no RFI than we can choose this path.

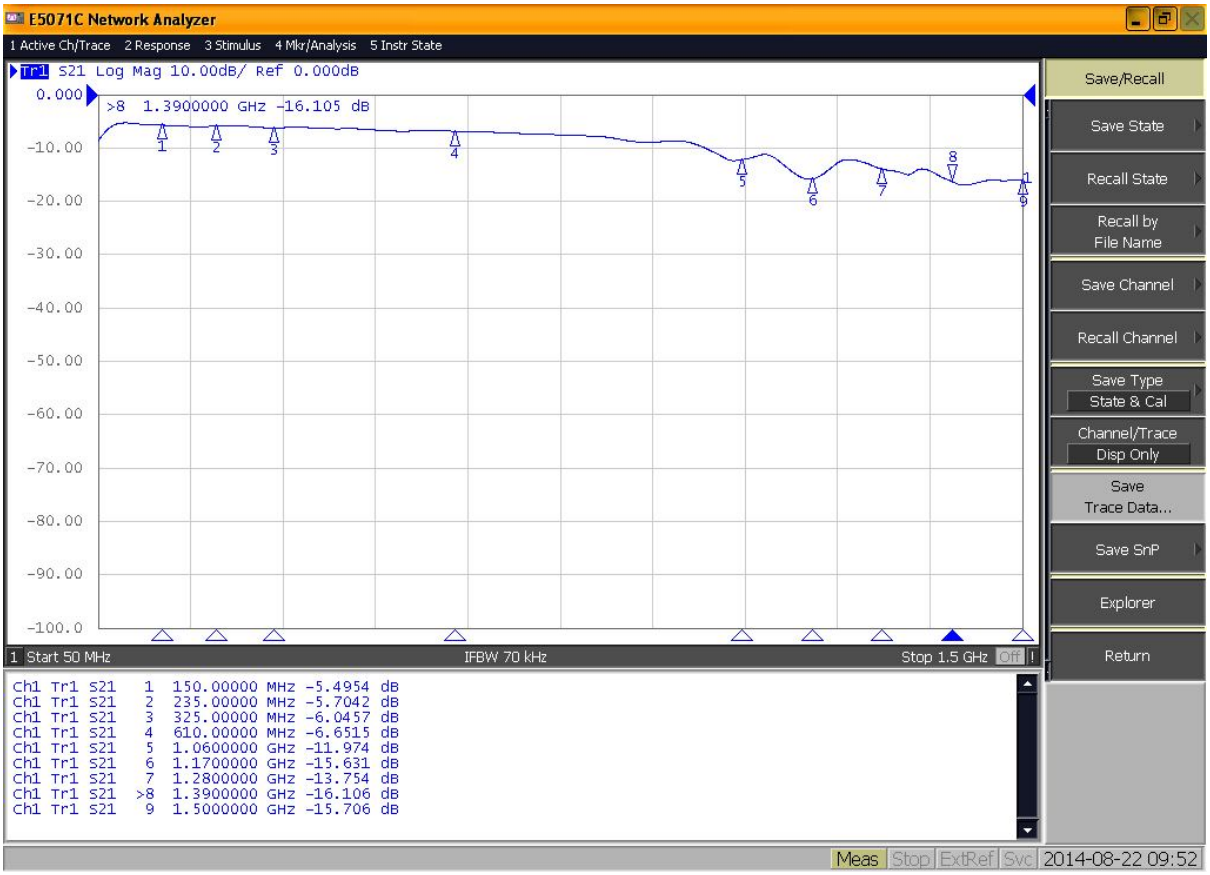


Fig. 12 By Pass mode

Conclusion:

It can be used in receiver room for RFI mitigation for GMRT observation bands and switching of Notch filters may be done as per requirement.

References:

1. G Swarup et al., " The Giant Meter-Wave Radio Telescope" Current Science, India,60, 2 January 1991, pp.97-105
2. Chris Bowick "RF Circuit Design"
3. P Raybole . "External sources of RFI at the GMRT" RFI2010, 29-31 March 2010, Gorningen, the Netherlands
4. Jia-Sheng Hong and M. J. Lancaster "Mirostrip Filters for RF/Microwave Application"