# Survey of Channelization Techniques For Digital Front End of Software Defined Radio

Mrs.Kirti S.Vaidya
SVPCET Nagpur
kirtivaidyain@yahoo.co.in

Dr.C.G.Dethe,
Director, Academic staff college
cgdethe@rediffmail.com

Dr.S,G.Akojwar
Associate Professor,
sudhirakojwar@gmail.com

**Abstract**
Channelizer is the main block in digital front of software defined radio. Main function of channelizer is to isolate the independent communication channel from the wideband input. In this paper a survey of different channelization techniques is presented. Various aspects of Channelizer are studied from multistandard mobile perspective. Challenges associated with channelizer are given.

***Keywords—*** *channeliser, software defined radio, multistandard mobile terminal.*

## I. INTRODUCTION

The term 'software defined radio' was proposed by J.Mitola in 2000.The concept indicates a change from system which are hardware dominated to systems which can be controlled by software. Variously software defined radio(SDR) is termed as 'reconfigurable radio' or flexible architecture radio'.Main advantage of these SDR is that these systems are flexible and can be easily reconfigured. This helps the communication receivers to receive many standards just by uploading the software. In SDRs all the components of a receiver like mixers ,filters, modulators and demodulators and detection circuits can be implemented through software.

In SDR receiver after antenna analog front end is followed by digital front end. The digital front end performs the function of channelization which means the capability to extract desired channel from wideband input signal. The channelizer has to select different channels of different bandwidth corresponding to different communication standards. Channelization includes digital down conversion ,channel filtering and sample rate conversion ,Channelizer is a block after ADC. It has to operate at highest sampling frequency. Therefore channelizer implementation requires efficient architectures.

Channelizer is the most important block in software defined radio. It is the focus of this paper. In this paper we consider application of SDR in mobile receivers. Various aspects of channelization are illustrated in Fig. 1.We start by introducing FIR filter theory in section II. Various techniques used for channelization are discussed in section III. Section IV explains challenges associated with channelization.

The goal of this paper is to consider and point out all aspects of channelization. These aspects are discussed in the rest of the paper.

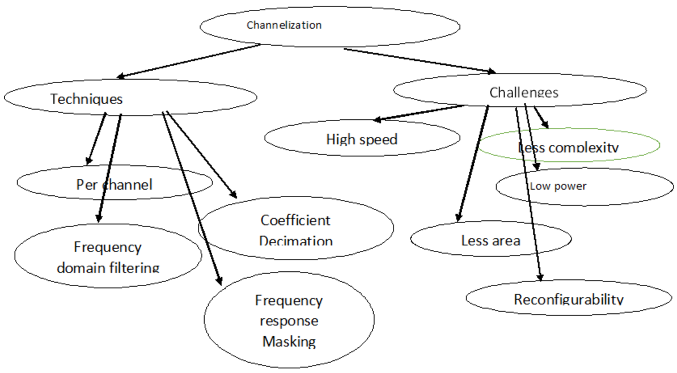


Figure.1 Various aspects of channelization

## II. FIR FILTER THEORY

A filter is essentially a network that selectively changes the waveshape of a signal .The objective of filtering is to improve the quality of a signal or to extract information from signals.[42]

A channelizer block of SDR is used to select the desired signal from wideband input signal. FIR filters have following advantages. FIR filter has advantage of having exact linear phase, stability. The design methods are generally linear and they can be realised efficiently in hardware. An FIR filter of length M is described by the difference equation

$$Y(n)=b_0x(n)+b_1x(n-1)+b_2x(n-2)+\ldots\ldots..+b_{M-1}x(n-M+1)$$
$$= \sum b_k\, x(n-k)$$

Where $\{b_k\}$ is the set of filter coefficients $b_k$.

## III. CHANNELIZATION TECHNIQUES

Main function of channelizer is to isolate the independent communication channel from wideband signal. Mainly FIR filters are used for this purpose. It is required to have a filter /filter bank whose bandwidth can be varied as per the communication standard. Channelization techniques can be of three categories digital down conversion, frequency domain filtering, polyphase FFT filters [22].

After reviewing the literature it is seen that channelization is done using various approaches like per channel approach, frequency domain filtering, Frequency response masking ,coefficient decimation .

A. Per channel approach[13]

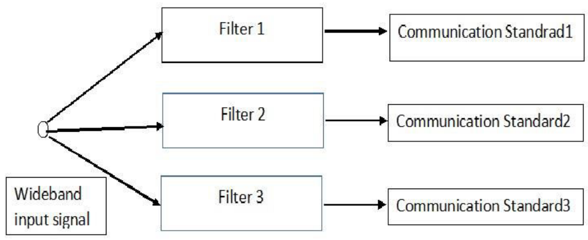


Figure.2 Per channel approach

Figure 2 shows block diagram representation of per channel approach. In per channel approach each channel is extracted using separate filter. Every standard requires a separate channel filter. As the number of stsndards grow complexity will increase. Per channel approach is very basic and it is not hardware efficient.[13]

B. Frequency domain filtering

In frequency domain filtering [22] FFT properties are used to achieve baseband conversion , filtering and decimation in digital down conversion. The diagram explains the frequency domain filtering technique. In this technique input data is split into overlapping blocks. The FFT bins give us frequency components corresponding to each channel of interest.

In [13] DFT filter banks(DFTFB) are reviewed. DFTFB is used when different channels of the same communication standard need to be received. DFTFB are restricted to uniform bandwidth signal .They can not extract nonuniform bandwidth signals. When multiple channels are to be extracted separate DFTFB and sample rate converters are required. It is a costly choice for multiple standards.

C. Frequency response Masking

In [39] a frequency response masking technique is proposed for the synthesis of sharp transition band FIR filters. In frequency response masking technique each delay element is replaced by M delay elements in linear phase low pass filter. .It gives (M+1) band filters .The transition width of this (M+1) band filter is 1/M of that of the low pass filter. A complementary filter is obtained by subtracting the output of (M+1) band filter from delayed version of the input. The passband of prototype filter is the stopband of complementary filter and vice versa. By combining and properly masking the frequency responses of original and complementary filter narrow transition band filter is obtained [39]

D. Coefficient decimation

Most of the papers [8] ,[11],[38],[39],[40],[42] coefficient decimation method is used for channelization. In coefficient decimation method first step is to design modal FIR filter. .The coefficients of FIR filters are decimated by M i.e. every $M^{th}$ coefficient is retained and all others are replaced by zeros. This method is referred as CDM-I. In [18] modal filter is designed and by changing M different filters with different frequency responses are obtained. These frequency responses are added/ subtracted to give various frequency responses. It helps to create filter bank for software defined radio. In CDM II modal filter is designed .Every Mth coefficient is retained and all other coefficients are discarded. The new filter has a bandwidth M times that of the proptotype filter. In [39] author proposes two methods a modified coefficient decimation-I (MCDM –I) and (MCDM-II). In MCDM –I a prototype filter is decimated by a factor of M, $M^{th}$ coefficients are unchanged and sign of every alternate retained coefficient is reversed. All other coefficients are replaced by zeros. This gives multiband frequency response with centre frequencies of subbands at odd multiples of pi/M. In MCDM-II every $M^{th}$ coefficient is retained and all others are discarded. The sign of alternate samples is reversed. This method gives a highpass frequency response with its bandwidth M times that of prototype filter[39].

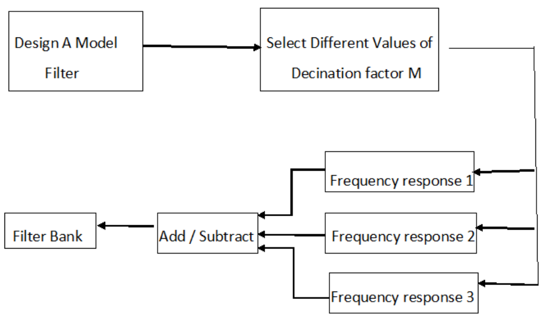


Figure.3 Block diagram of coefficient decimation method

In [8] new methods ICDM-I and ICDM-II are proposed .ICDM-I is a combination of CDM-I and MCDM-I and ICDM II is a combination of CDM-II and MCDM-II. Using ICDM-I center frequency resolution of pi/M can be obtained for subbands. On the other hand using

ICDM-II subband bandwidths that are integer multiples of prototype filters are obtained.

## IV. CHALLANGES

The challenges before channelization process are shown in figure 1.These challenges are discussed here.

### A. Speed

When dealing with real time applications like digital advanced mobile phone system one of the desirable charactristics of a channel filter is speed. High speed operation is the key requirement of channel filter .Efforts are made to improve the speed of a channel filter. In [42] a high speed canonic signed digit based reconfigurable FIR filter is presented.

In [12],[15] residue number system based FIR channel filter is proposed. RNS is defined by a moduli set which consists of some pairs of relatively prime integers .A computational range of such a number system is nothing but the product of all moduli. Any integer has a unique RNS representation that is characterized by its residue. In [12 ] 42% improvement in speed is achieved. It is advantageous over the high speed CSD method in area and delay. A drawback of RNS is the need for converters to/from the conventional number system. However for high order filters in SDRs this conversion overhead has a small impact.

### B. Low power

Improving the energy efficiency of mobile terminals faces a challenge as network operators migrate from 2G,3G to 4G.In power constrained mobile terminals the available power budget is only 1 watt. SDR provides a solution to this problem by using flexible hardware .Flexibility however increases a power consumed.[20]These demands of flexibility and low power are conflicting. In [20] a low power implementation of programmable time shared filters is proposed.

### C. Complexity

In[13] a non uniform filter bank is proposed which can be used for channelization in multistandard wireless communication receiver. The complexity term is discussed here with respect to multiplication operation .In signal processing multiplication operation is complex and power consuming .Author in [13] compares the proposed filter bank with other FBs in terms of multiplications. It is shown that number of real multiplications is less. Also area consumed by the FB is proportional to number of multiplications. Hence reducing multiplications reduces area. In [18] a coefficient decimated filter bank is proposed. Here the coefficients of an FIR filter are decimated by M. If N tap filter has N multiplications coefficient decimated filter will have N/M multiplications. Hence reduced complexity .In [14] author proposes new common subexpression elimination method to reduce complexity. It represents coefficients by binary representation .The number of addrers are reduced and thus reducing complexity. In [21] a term multiplication complexity is used. Multiplication complexity of a channelizer is defined as the total number of multiplications for extracting N number of channels simultaneously. The author gives comparison of multiplication complexities of various filter banks including per channel, DFTFB ,GFB, MPRB, FRMFB, CDFB. Multiplications associated with DDC, modulation of filters are compared separately.

### D. Reconfigurability

Reconfigurability is the most necessary requirement for channelizer in SDR as SDR has to serve multiple standards. In literature [12],[15],[8] propose single filter and in [13],[18] a filter bank is proposed .In[12] a reconfigurable filter is suggested in which filter coefficients corresponding to different standards are stored in look up tables. But in proposed method coefficient values of filters are stored in a LUT with respect to their residue values. Hence the coefficients to be stored enjoy less area. A similar structure is proposed in [15] and encoder is used to select a product value. In [8] a variable digital filter for SDR is proposed based on improved coefficient decimation method. Different bandpass frequency reponses are obtained by changing the decimation factor.

A filter Bank is a combination of filters. Two types of filter banks are proposed. Uniform filter bank and non uniform filter bank. A uniform filter bank is capable of extracting channels of same bandwidth and non uniform filter bank is capable of extracting channels of different bandwidths. In the literature two different levels of reconfigurability are discussed: Filter level and architecture level.

## V. CONCLUSION

Cognitive radio is one of the efforts made to utilize the available spectrum efficiently. To realize the concept of cognitive radio intelligent reconfigurable radios are required. In this paper a channelizaton block of software defined radio by taking into account different dimensions. Various aspects of channelizer with respect to multistandard mobile terminal are explained in detail. Some new technique to have reconfigurability , increasing speed ,reducing power ,area and complexity are considered as some of the open research areas.

## REFERENCES

[1] J. Mitola J. (2000).Software radio architectures, John Wiley.

[2] A technical review of software defined radios: vision, reality and current status, Lawrence Goeller, David Tate.

[3] Tore Ulversoy,"Software defined radio: challenges and Opportunities"in IEEE Communications Surveys and Tutorials,Vol 12,No.4,Fourth quarter 2010.

[4] Flexible multistandard terminals for 2nd and 3rd Generation Mobile Systems, Bernd Friedrich, ezakarimi.

[5] R.Mahesh,Vinod A.P.,"Frequency response masking based reconfigurable channel filters for software defined radio receivers."in Proc.IEEE Int.Sym.Circuits Syst. New Orleans. LA, May 2007,pp 4515-4518

[6] Kondali R.K.,"DDC and DUC filters in SDR platfroms", conferences on Advances in communication and control systems, 2013

[7] James T.George, Elizabeth Elias, "Reconfigurable channel filtering and digital down conversion in optimal CSD space for software defined radio", volume 68, Issue 4, April 2014

[8] Abhishek Ambede , A.P.Vinod ,"Design and realization of variable digital filters for software defined radio channelizers using improved coefficient decimation method", accepted for future issue of IEEE transactions on circuits and systems,2015

[9] P.K.Devi,R.S.Bhuvaneswaran, "Improved Non uniform transmultiplexers for channelization" in Indian Journal of Science and Technology, volume 8, Issue 5, March2015

[10] Isael Diaz,Chenxin Zhang "A new digital front end for flexible reception in software defined radio" in press, Microporocessors and Microsystems, Elsevire, April 2015

[11] S.K.Darak, A.P.Vinod,"Design of variable linear phase FIR filters based second order frequency transformations and coefficient decimation"

[12] K.G.Smita , A.P.Vinod ,"A reconfigurable channel filter for software defined radio using RNS",Journal of signal processing syst,2012,pp 229-237

[13] Sumit Darak, A.P.Vinod,"A low complexity reconfigurable non uniform filter bank for channelization in multistandard wireless communication receivers" Journal Signal Processing Syst.(2012)j

[14] R.Mahesh ,"Reconfigurable frequency response masking filters for software defined radio channelization" IEEE Transactions circuits and systems, Vol 55,No 3,March 2008

[15] Smita K.G. and A.P.Vinod ,"A reconfigurable high speed RNS FIR channel filter for multistandard software radio receivers"2008

[16] Sumit J.Darak, Vinod A. Prasad, Edmand M.K.Lai, "Efficient implementation of reconfigurable warped digital filters with variable low pass ,high pass ,bandpass and bandstop responses "IEEE Transactions on very large scale integration systems,vol 21,No. 6 June 2013

[17] Ojowari, Otunniyi, Ogunti ,"Digital front end for software defined radio wideband channelizer"

[18] R.Mahesh and A.P.Vinod ,"Reconfigurable Filter banks for software defined radio receivers –An Alternative low complexity design to conventional DFT filter banks"

[19] Mehmood-ur- Rahman Awan, Peter Koch,"Polyphase channeliser as band pass fiters in multi standard software defined radios",Proceedings of 1st international conference on wireless communication,VITAE,2009

[20] Navin Michael, A.P.Vinod ,"Low power ,Flexible FIR filters in the digital front end of green radios"

[21] Mahesh Panicker ,A.P.Vinod ,"Filter bank channelizers for multistandard software defined radio receivers"in journal of signal processing systems, vol 62,pp-157-171,Feb.2011

[22] Lee Plucker,"Channelisation techniques for software defined radio"

[23] Lin Fei-yu,Qiao Wei-ming,Zhang Jian chuan,Nan Gang-yang,Li Wei-bin,MAO Wei-yu,Second International Conference on Network Security,Wireless Communications and Trusted Computing

[24] Diaz I,Chenxin Zhang,Hollevoet,"Next genearation digital front end for multi-standard concurrent reception"published in IEEE conference NORCHIP , Nov.2013

[25] P.Kalpana Devi, Bhuvaneswaran R.S.,"Flexible reconfigurable filter architecture for SDR receiver" IEEE Malaysia International Conference on communications,2013

[26] Nagesh Bhat,"Design and ASIC implementation of DUC/DDC for communication systems",2012

[27] N.Ito and T.L.Deng,"Variable bandwidth filter-bank for low power hearing aids",in Proc.3rd Int. Image Signal Processing,vol.7.Oct.2010,pp3207-3211

[28] S.J.Darak, A.P.Vinod and E.M.K.Lai,"A new variable digital filter design based on fractional delay,"in Proc.IEEE Int.Conf. Acost. Speech Signal processing,May 2011 pp 1629-1632

[29] Kim C., Shin Y.,Im S. & Lee.W,"SDR-based digital channelizer/dechannelizer for multiple CDMA signals",in Proceeding of IEEE Vehicular technology Conference,2000,vol. 6,pp429-432

[30] Zangi K. & Koilpillai,R. ,"Efficient filter bank channelizers for software radio receivers",in International Conference on Communications,vol.3,pp 1566-1570.

[31] Matti Etalapera, Juha-Pekka Soininen,"4 G Mobile Terminal architecture",VTT Technical report,Nov-OCT 2007

[32] A.G.Dempster and M.D.Macleod,"Use of minimum adder multiplier blocks in FIR digital filters"IEEE Trans. Circuits Sys. II ,Analog Digital Signal Process,Vol 42,no.9,pp569-577,Sep 1995

[33] S.C.Chan, C.K.S.Pun and K.L.Ho,"A new method for designing FIR filters with variable characteristics"IEEE Signal Process.letter,vol11,pp274-277,Feb 2004

[34] Dermisoy, S.S.Kale, I.Dempster, A.G.,"Efficient implementation of digital filters using novel reconfigurable multiplier blocks."In Proceeding of Thirty Eighth Asilomar Conference on Signals ,Systems and Computers,vol 1,pp461_464

[35] Benjamin Egg, Fredric Harris ,Chris Dicck,"Ultra-wideband 1.6 GHz channelizer :Versatile FPGA implementation "in proceeding of the SDR 05 Technical Conference and Product Exposition ,SDR Forum 2005

[36] T.Solla and O.Vainio,"comparison of programmable FIR filter architectures for low power "in Proc.28th ESSCIRC,Florence Italy,Sept 2002

[37] K.H.Chen and T.D.Chiueh,"A low power digit based reconfigurable FIR filter"IEEE transactions on Circuits Syst.II exp.Briefs,vol 53,no.8,pp 617-621

[38] Y.C.Lim, "Frequency response masking approach for the synthesis of sharp linear phase digital filters,"IEEE transactions on Circuits Syst.,vol 33,no. 4 pp357_364,Apr.1986

[39] A.Ambede, K.G.Smitha and A.P.Vinod,"A modified Coefficient decimation method to realize low complexity FIR filters with enhanced frequency response flexibility and passband resolution" in Proc.35th Intl.Conf,TSP,Prague,Czech Republic ,Jul 2012,pp 658_661

[40] A. Ambede, K.G.Smitha and A.P.Vinod,"A low complexity uniform and non-uniform digital filter bank based on an improved coefficient decimation method for multi-standard communication channelizers"Springer Circuits Syst. Signal Process.,vol 32,no.6,pp 2543-2557

[41] Mahesh R.& Vinod A.P.,"Coefficient decimation approach for realizing reconfigurablefinite impulse response filters.Proceedings of IEEE international symposium on circuits and systems. Seattle USA,May.

[42]S.Salivahanan,A.Vallavraj,C.Gnanapriya,"Digital Signal Processing"