Digital Audio Broadcasting Based Gfdm Transceiver Using Software Defined Radio

Nagarjuna Telagam, S Lakshmi, K Nehru

Abstract: This article is devoted to an interesting educational direction i.e. Radio Frequency (RF) concepts and the use of basic digital signal processing tools for the development of real-time applications. A system with digital audio broadcasting (DAB) based generalised frequency division multiplexing (GFDM) is considered, estimates of its transmission modes are utilized. Software Defined Radio (SDR) is an advanced radio which can tune to any recurrence band and goes about as handset by utilizing universal software radio peripheral device (USRP) Programmable with LabVIEW programming. In this paper GFDM system proposal for digital audio broadcasting is investigated. The kernel is GFDM system, Emphasis is on the use of channel coding with low-density parity-check and convolutional codes at the transceiver. Furthermore, by using LabVIEW RF communications module software, a transceiver platform is built-up to analyze the performance of the DAB channel based on USRP hardware set up. BER is calculated under rural area (RA) consideration for entire area with quality of audio signal received is mentioned with different colours along with goggle map. This experiment was successfully conducted in GITAM University, India. The paper concludes with better audio quality of GFDM and slightly outperforms OFDM in terms of BER by a margin of 13% in the RA only.

Index Terms: BER, DAB, GFDM, SDR.

I. INTRODUCTION

5G reviews the state-of-the-art in mobile and broadcast technologies and the current trends for convergence between both industries.The digital future has many research directions for fifth generation. The digital audio broadcasting technology plays a key role in the multimedia environment and it was launched by Eureka Company. EUREKA 147 DAB system includes the Internet [1]. Coded OFDM is used to transmit DAB signal with high quality of sound using rugged method of transmission [2]. DAB can be used for mobile reception in the range of frequency range of 30 MHz to 3 GHz. This technology supports audio programmes with different range of sound coding rates and it can carry a number of services with digital multiplexing feature. According to ITU, DAB technology is only one which meets the demanding requirements in the entire world. It also opens horizons for all digital broadcasting in the future [3]. DAB receivers are allowed to uniformly process the video services to achieve high spectral efficiency in video service processing and controlling [4]. The computerized predistortion system is appropriate for wideband high peak factor applications, for example, advanced sound telecom, and computerized video broadcasting. This method avoids the problems in direct conventional method [5]. This paper addresses the I/Q mismatch problem in zero forcing OFDM receiver and it applied in DAB technology. The authors employed a decision directed with least mean squared algorithm with frequency adaptive method to the demodulation section [6]. The Simulation model is proposed which accurately predicts the performance of DAB transmission channels. The Embedded compiled C-code subroutines incorporate regulation conventions, blunder rectification and MPEG layer-2 perceptual sound coding. Software is PC compatible with both DAB system and transmission channel configurable using a bespoke graphical user interface, which facilitates changing on the fly modulation and transmission-path related parameters [7]. The problems in FM such as low quality on audio signal, interference etc is resolved in DAB technology. This article proposed and DAB system using OFDM with an input of audio signal and its performance is calculated using BER with respect to SNR values [8]. DAB is simulated with various types of diversity channels in MATLAB and SIMULINK software for all the conceivable four modes the fourth mode has great level of BER performance ranging between 20% to 22% [9]. The table of rows and columns are demonstrated with forward error correction (FEC) in the decoder section for the error correction [10]. OFDM based DAB is implemented using rectangular pulse shaping with different channel coding techniques such as Rate Compatible Punctured Convolutional (RCPC) codes, convolutional codes. The unequal error protection is implemented in this model which uses data services into consideration [11]. The DAB performance is analysed using Xilinx Alliance tools and Xilinx XSE & ISE and modelsim XE software with including noise interference and fading effects [12]. A software defined radio performs signal processing operations with the help of labVIEW software and OFDM radio signal is transmitted using USRP device and its quality of service is measured in terms of Packet received ratio [13].Cognitive radio is one of the technologies which plays an vital role in the RF spectral scarcity. The spectrum sensing can be analysed using GNU radio system with USRP device.

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The authors analysed the spectrum range for settled data transfer capacity over an observation time window with period of T sec [14]. The USRP device is family of products is now become an hardware based research in SDR and Cognitive radio (CR) fields. This device has been using in universities, teaching laboratories and class rooms. The device helps in understanding more advanced topics in signal processing and communications [15].The survey conducted in grand forks with a frequency range of 824 MHz to 5.8 GHz for evaluating the spectrum usage of radios. This survey uses GNU radio software and SDR. The results show that the proposed techniques are more effective in scanning and evaluating the spectrum and overcome the conventional methods such as energy detection and auto correlation methods [16]. Medical companies has been utilizing the wireless communications devices in the ISM bands especially the unlicensed 2.4 GHz band which causes interference such as Wi-Fi, ZigBee and Bluetooth. For patient safety measurements the SDR device is used to measure the channel duty cycle, packets arrival rates, nodes distributions and packet inter- arrival time distribution of IEEE 802.11 a/g networks[17]. The practical communication systems challenges and drawbacks are demonstrated using NI USRP devices for the students and educational trainers is explained [18]. The USRP device has many applications here the RADAR system is implemented with peripheral USRP 2920 and demonstration proved that an improvement in target resolution with respect to the conventional system [19]. The FPGA implementation of GFDM is presented in this paper. This system is reconfigurable at run time in any moment in front panel of LabVIEW. GFDM is one of the candidate waveform which addresses all degrees of freedom for fifth generation [20]. The MIMO-GFDM configuration is implemented using NI USRP-RIO which supports today's technology [21]. The GFDM waveform has flexibility in pulse shaping filter and this helps in designing different applications such as cognitive radio, tactile internet and Wireless Radio Access Network (WRAN) applications. This paper gives the detailed experimental validation of GFDM waveform in Long term Evolution (LTE) system. GFDM-CR waveform is generated with improved sensing performance and compared with OFDM-CR waveform and this new waveform has high spectral efficiency and produces less number of false alarms in Cognitive radio technology [22]. This paper presents gr-gfdm based SDR implementation in GNU radio platform is demonstrated and it achieves a sampling rates of up to 25 MS/s [23]. The upcoming industry 4.0 closed loop control applications require low latency time. GFDM waveform measures the latency using GNU radio framework. The investigation of this proposed scheme is done in the SDR platform; the low latency broadband systems are more feasible for I4.0 applications [24]. This manual gives the basic idea of programming any communication system in LabVIEW communication design suite. [25]. The VI snippets are designed in the transceiver are taken from the reference [26], [27]. The USRP 2901 is used to design as FM transceiver with different frequencies [28]. The simulation of analog modulation and demodulation schemes in virtual instrumentation are explained in [29].

II. DAB-GFDM SYSTEM MODEL USING USRP DEVICE
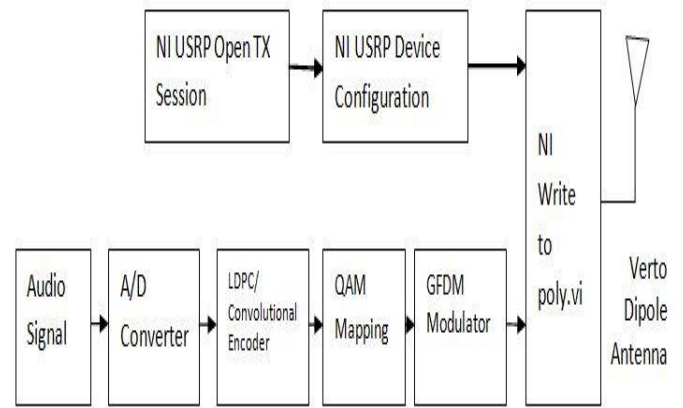
Fig. 1. DAB-GFDM System Model

Figure 1 shows the implementation steps of Digital audio broadcasting system using USRP 2901. The session was opened using vi program which is inbuilt. Then we configure the signal with active antenna, gain in dB, carrier frequency of the antenna using NI USRP configure signal utility. We have used input as sound file and converted the analog data to digital signal using the icons in the lab view. QAM mapper converts bits to symbols. The QAM uses only ones and zeros as input and then output of signal mapper block is connected to GFDM modulator which is explained in the figure 2.
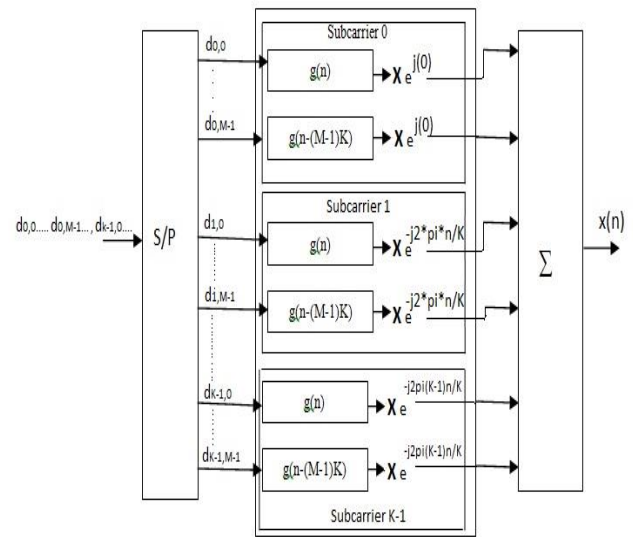
Fig. 2. GFDM Modulator Block diagram

$$g_{k,m}[n] = g[(n-mk) \bmod N].e^{[-j2\pi\frac{k}{K}n]} \quad (1)$$

$$x[n] = \sum_{k=0}^{K-1}\sum_{m=0}^{M-1} g_{k,m}[n]d_{k,m} \quad (2)$$

$$\vec{x} = G\vec{d} \quad (3)$$

The resulting vector denotes a data block that contains N elements, which can be decomposed into K subcarriers, with M, sub symbols each according to the total number of symbols follows as N = KM. $\bar{d}$ =, ,..... $\overline{d_{0M-1}^{T}}$)

$\bar{d}$ = (, ,..... $\overline{d_{K-}^{T}}$ ^{T} The two inputs are given to NI USRP write to poly.vi with different data types of data. One is the pink colour wire coming from configure signal VI and orange colour wire which is the output of GFDM waveform is connected to write to poly.vi. Finally the Verto dipole antenna which supports tri band of frequencies is used to transmit the data. Figure 3 shows the schematic block diagram of the receiver which has USRP 2901device with verto dipole antenna. After sequential steps the output data bits are recovered from the channel decoder.
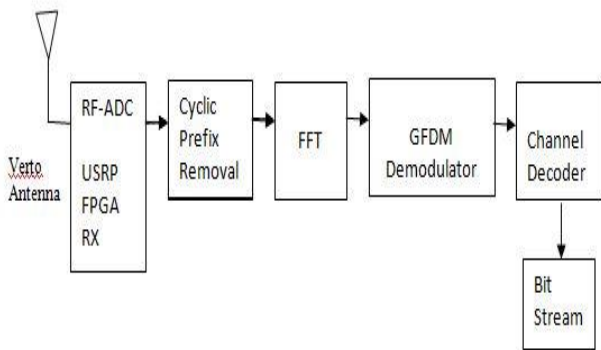
Table 1. USRP device specifications.

S.NO	PARAMETERS	RANGE
1	Frequency Range	70 MHz to 6 GHz
2	Gain of USRP device	89.75 dB
3	DAC	12 bits
4	Maximum input power	-15dBm
5	Maximum output power	20dBm
6	Vert2450 antenna frequency range	2.4 to 2.48 GHz
7	Antenna Gain	3dB
8	Radiation pattern	Omni-directional
9	Polarization	Vertical

Fig. 3. DAB-GFDM receiver block diagram using USRP device Configuration

A. *DAB-GFDM Demonstrator*

Figure 4: Hardware setup of Experiment

The USRP devices have two RF modules i.e. RF0 and RF1 in which the Verto Dipole Antennas are attached. Table 1 shows the USRP device specifications used in the design process as shown in the figure 4.
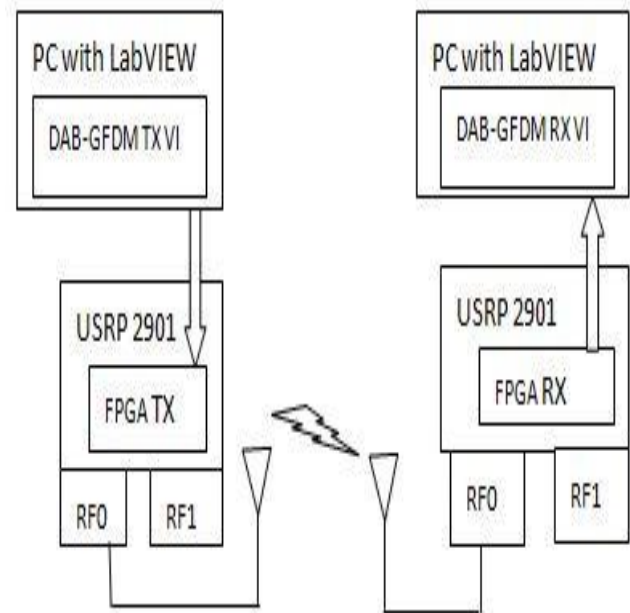

Fig. 5. USRP-DAB-GFDM Demonstrator

Figure 5 shows the schematic data programming flow of the entire experiment. It shows two USRP devices communicating audio signal using fifth generation waveform named as GFDM. The LabVIEW communications software along with modulation tool kit, USRP device drives are installed in the PC.
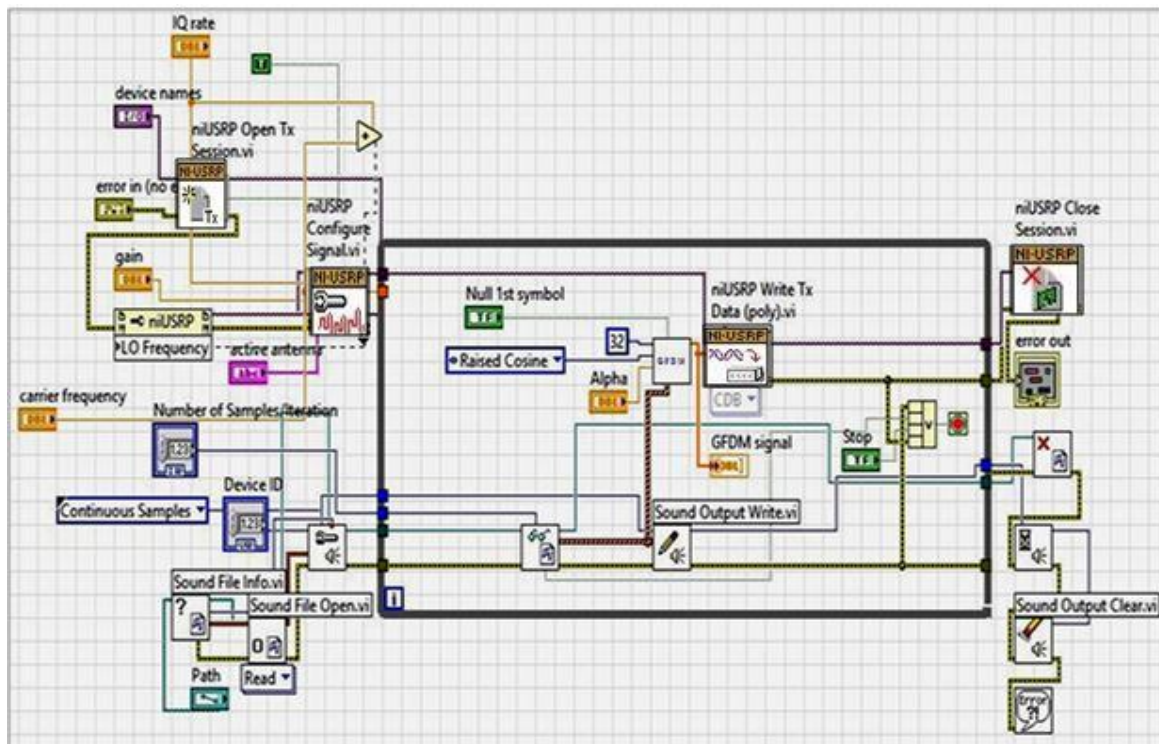
B. Implementation of VI Transceivers

Fig. 6. DAB- GFDM Transmitter Main VI Program

Figure 6 and table 2 shows the main VI of the digital audio broadcasting transmitter, it uses different VI's such as sound file read, sound output write and sound output clear, and their operations are explained in the table 2. The session is started by integrating the device with the computer and then the specifications are given by the user.

Table 2. List of VI's used in GFDM Transmitter

VI NAME	FUNCTION
Ni USRP open Tx session.vi	Opens a transmit session to the device(s)
Ni USRP configure.vi	Configures properties of the transmitter
Ni USRP write Tx Data (poly).vi	Writes data to the specified channel list.
Sound file info.vi	Retrives data about .wav file
Sound file read.vi	Opens a .wav file for reading
Sound output configure.vi	Configures a sound output device to generate data
Sound file read.vi	Reads data from a .wav file into an array of waveforms
Sound output write.vi	Write data to sound output file
Sound output clear.vi	Stops the device for playing sound

IFFT.vi	Performs inverse fast Fourier transform

Table 3. Parameters used in the VI programming

S.NO.	PARAMETERS	SYM	VALUE
1.	Filter parameter(Root Raised Cosine	α	0.5,0.2,0.3
2.	Digital Inphase and Quadrature Rate	IQ	5M Samples/sec
3.	Transmitter Carrier Frequency	F_{ct}	1 GHz
4.	Transmitter and Receiver Gain	G_t, G_r	6 dB,8 dB
5.	No of subcarriers	K	1536
6.	No of sub symbols	M	5
7.	No of symbols/Frames	N	7680
8.	Received carrier frequency	F_{cr}	2GHz

Table 3 shows the parameters used in the Virtual instrumentation programming in both the transmitter and receiver.
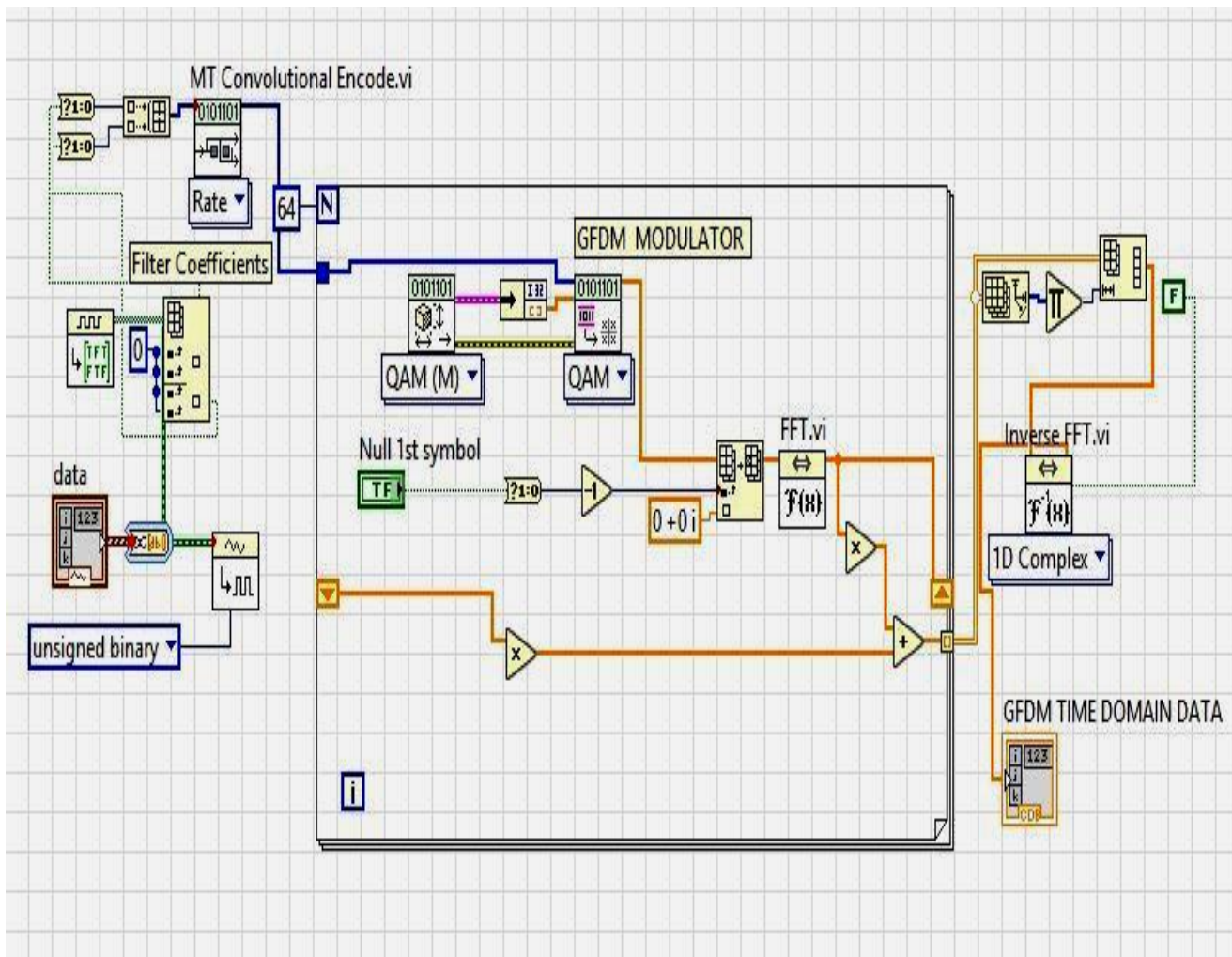
Fig.7. DAB- GFDM Transmitter SUBVI Program

The input path is taken from the drive in .wav format. This audio file is been given input to the GFDM modulator as shown in Figure 7. The sub VI takes the audio data in array form and with respect to filter coefficients and it is encoded using convolutional and LDPC codes. The output is shown in figure as GFDM time domain signal.

Table 4. Parameters of DAB transmission modes

NO OF SUBCARRIERS	SUBCARRIER SPACING	SYMBOL TIME	CARRIER FREQUENCY	TRANSMITTER SEPARATION
192	8kHz	155.8µS	<3GHz	<12Km
1536	1KHz	266.2 µS	375MHz	<5Km
384	4KHz	666.6µS	1.5GHz	<10Km
768	2KHz	133.3µS	750MHz	<20Km

Table 4 shows the four modes of operation of DAB. Usually in DAB, four different transmission modes are used; each and every mode has different variety of applications. Mode 1 operates for VHF applications such as broadcasting, PPDR, Marine time, Land mobile, Aeronautic or aviation, Armature Radio, satellite and radar which includes aeronautical engineering. Mode 2 operates in L-band Frequency and used in static line and power line applications. Mode 3 operatives in satellite frequency i.e. from L, S, C, X, Ku, K, Ka bands in GHz Frequency. Finally Mode 4 works in UHF band and used in many applications such as UHF-TV broadcasts.
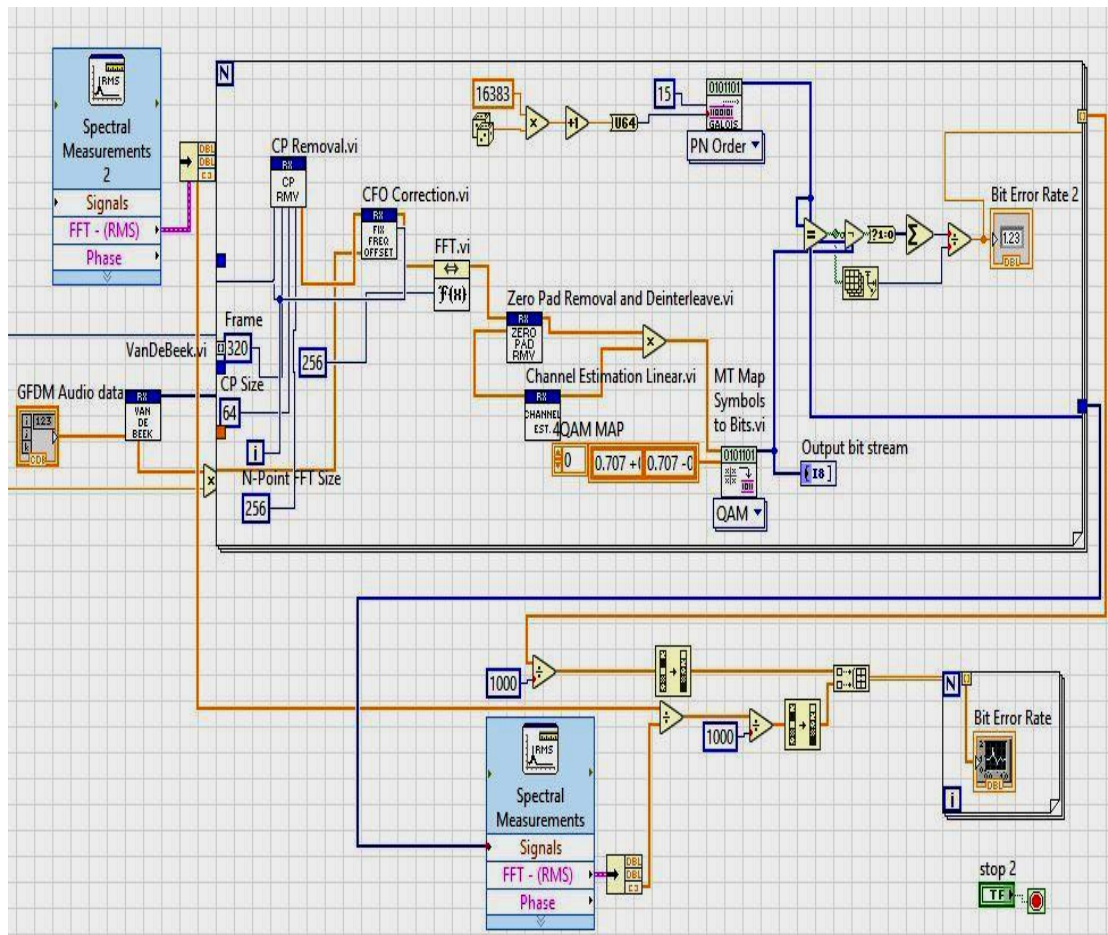
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Fig. 8. Digital Audio Broadcasting Receiver VI Snippet USRP configuration

Table 5. List of VI used in Receiver of GFDM

VI USED	FUNCTION
Ni USRP open Rx session.vi	Open receiver session
Ni USRP configure signal.vi	Configures the signal
Ni USRP initiate.vi	Initiate the process
Ni USRP Fetch RX Data (poly).vi	Fetches complex, double-precision floating-point data in a waveform data type from the specified channel
Ni USRP Abort.vi	Stops the receiving session
Ni USRP Close session.vi	Close the session
VanDeBeek.vi	Maximum likelihood symbol time and carrier frequency estimator
CP removal.vi	Removes cyclic prefix
CFO correction.vi	Corrects carrier frequency offset
FFT.vi	Performs FFT
Zero Pad Removal and Deinterleave.vi	Removes zero padding and deinterleaves data and extracts reference symbol
Channel estimation.vi	Estimates channel based on received reference symbols and known reference symbols
BER.vi	This polymorphic instance calculates the average BER against a Fibonacci PN sequence.

Figure 8 shows the receiver section using USRP device and its corresponding VI's are explained in the table 5.
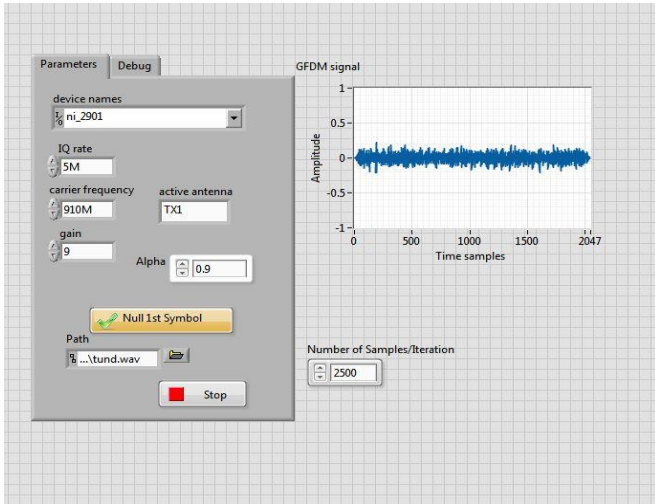
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III. RESULTS AND DISCUSSIONS

Fig. 9. Screen shot of Front panel in LabVIEW

The figure 9 shows the sound file is taken as input with the help of path. The icons such as sound read, sound write is used. The device ID is used and we have configured the signal. We have converted the analog signal to digital signal using dynamic data type icon along with analog to digital. VI, and given to array subset. We have checked the data using appended array and confirmed the output which has only ones and zeros. 4-QAM mapping is used and we have converted the serial data to parallel data with the help of arrays. This parallel data is given to IFFT.VI, which converts frequency domain representation to time domain representation. We have connected the output of IFFT along with guard band interval to NI USRP write to poly.VI which transmits the audio signal through Verto tri band antenna.
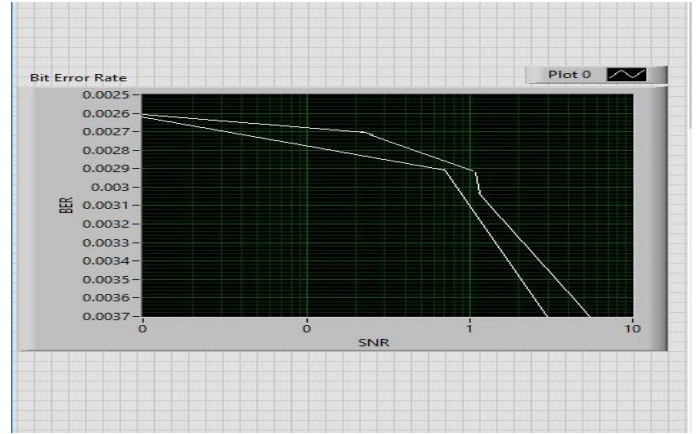

Fig 10. Screen Shot of Receiver Front panel

Fig 11. Screen Shot of BER plot from Front panel

Figure 10 and Figure 11 shows the phase, magnitude and theta responses for different values of amplitudes with respect to time, bit error rate graph with respect to SNR values. The quality of audio signal is good when the BER range is above 0.003(green color). The Bit error rate is recorded low in the fraction of 400 seconds because of dense region with trees. This phenomenon is explained with different colours along with route as shown in figure. The Red color is where the signal is not receiving and it is almost mute. The pink color is where the BER is slightly higher and the quality of signal is less.
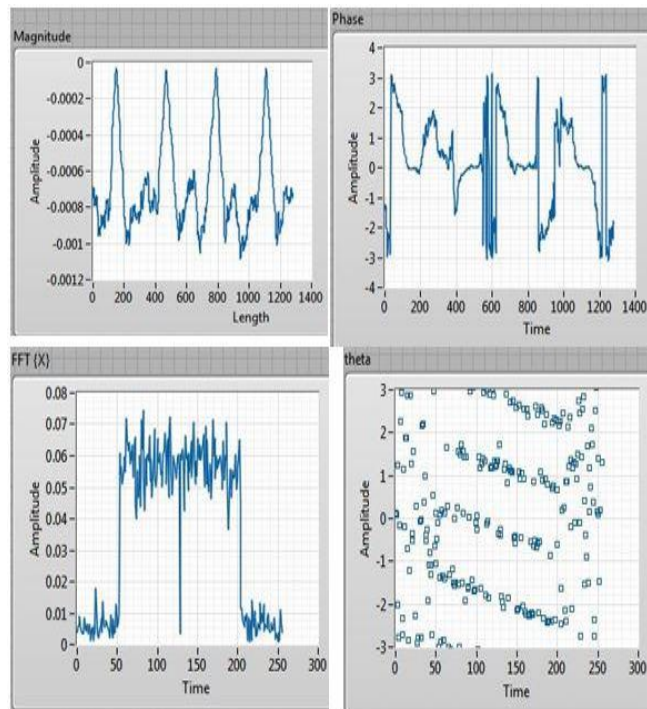

Fig 12. BER (audio quality) of Verto Receiving antenna signal

Table 6. Audio signal quality

AUDIO QUALITY	COLOR	BER
High	Green	$BER < 2.6 \times 10^{-4}$
		$2.6 \times 10^{-4} < BER < 2.8 \times 10^{-4}$
Disturbed	Pink	$3 \times 10^{-4} < BER < 3.4 \times 10^{-4}$
		$3.4 \times 10^{-4} < BER < 3.6 \times 10^{-4}$
Mute	Red	$BER > 3.7 \times 10^{-4}$

The aim for our experimental platform was to broadcast the digital audio signal using GFDM technique. The 2 USRP devices with digital data interface and a general purpose DSP tools are used for signal processing in LabVIEW. This RF-0 and RF-1 tuners covers the four bands of frequencies and these USRP devices works in the range of 75MHz-6GHz. The RF Communications module inside the labVIEW includes the transceiver chain which consists of synchronization, estimation, demodulation, channel decoding and decoding of audio signal. The receiver has the ability to decode the signal from the Verto antenna. The BER has plotted for this received audio signal with the input signal. The performance of the receiver was verified with distance between transmitter and receiver and this simulation suits for rural area channel [RA]. With the help of goggle gaps the receiver operation is tested with the quality of audio signal as shown in table 6 and Figure 12.

A. Computation location

First DAB transmitter is located in the Virtual instrumentation lab. The transmitter is situated at 13.2866° N, 77.5951° E respectively. The receiver is located at 13.2957° N, 77.5364° E and it is moving with respect to vehicle. These locations are separated by approximately 1Km (1000 meters).

B. Computation analysis

The relation between the audio quality and the BER was evaluated in the virtual instrumentation laboratory with real time received signal on the basis of rural area channel. BER plots are plotted with audio quality is good or bad.

C. Computation results

The receiver has driven in and around 1km range to check the signalling strength. The environment is rural area. The Verto receiving antenna supports three bands of frequencies. The antenna is not affected by line of sight problem. The BER is visualised in the below figures with respect to the quality of audio signal. In addition to BER plots the complete routes of goggle maps is presented with different colours. The three colour lines correspond to the BER intervals as shown in the table 6.

IV. CONCLUSION

As the digital radio market continues to increase the growth daily and its demand for reliable and efficient services need high quality audio signal for future generations. This can be satisfied using National instruments based USRP device. Here in this article the Digital Audio Broadcasting system using GFDM is implemented using a USRP 2901 with tri-band antenna. The real time data is sending over 75MHz-3.5GHz frequency with distance of nearly 1Km. The simulation results found that with the help of working set up the GFDM waveform can able to transmit the digital audio signal with different channel coding techniques using USRP RIO device. The bits are successfully received and its error plot is shown in the figures. In other words this USRP transceiver device is successfully tested and quality of received signal is shown with different colours with respect to bit error rate. These field tests are conducted with VERTO tri band antenna in rural area configuration the BER is plotted using Google maps. The paper concludes with better audio quality of GFDM signal and slightly outperforms OFDM

based transceiver in terms of BER by a margin of 15% in the rural area only.

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