

Universität Duisburg-Essen
Fakultät für Ingenieurwissenschaften
Fachgebiet Hochfrequenztechnik (HFT)

Bachelor Thesis
RDS Encoder for the Campus Broadcast Sender

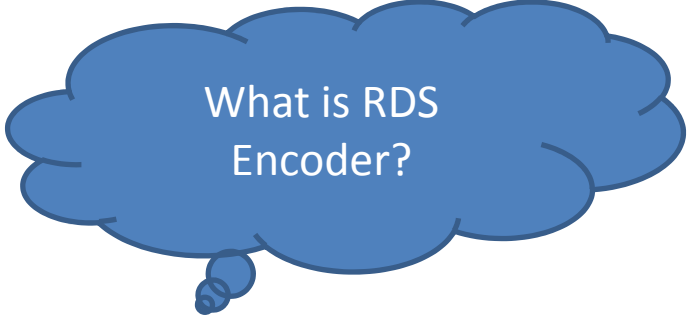
Poorya Hajian

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Zweitgutachter:
Prof. Dr.-Ing. A. Beyer

June 2009




What is RDS
Encoder?

Radio Data System, or RDS, is a communications protocol for **transmitting small amounts of digital information like Program service identification, Program identification** by using conventional FM radio broadcasts to send information over a communications channel standard from the European Broadcasting Union.

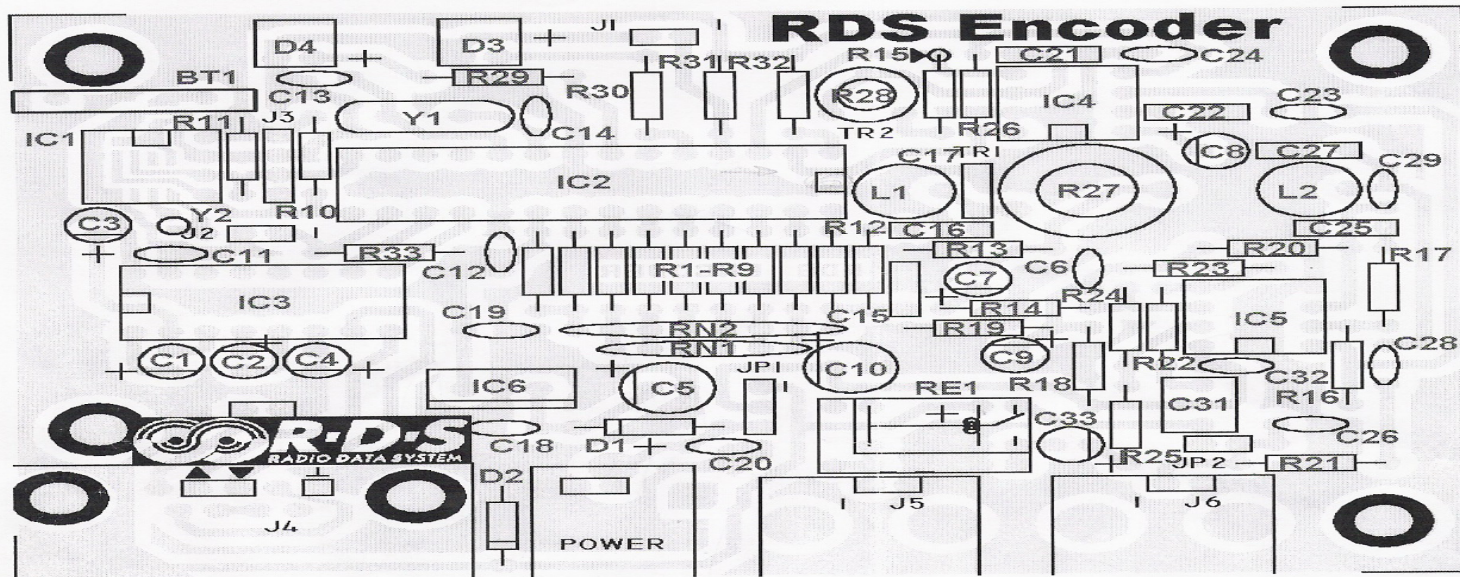
Usage of RDS



The RDS system contains several types of information transmitted, including time, track/artist info and station identification which is the practice of radio or television stations or networks identifying on air.



The Radio Data System, RDS, is intended **for application to VHF/FM sound broadcasts in the range 87.5 MHz to 108.0 MHz** which may carry either **stereophonic (pilot-tone system) or monophonic programs**. The main objectives of RDS are to enable improved functionality for FM receivers and to make them more user-friendly by using features such as Program Identification, Program Service name display and where applicable, automatic tuning for portable and car radios, in particular.



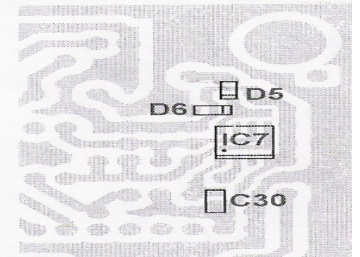
IC1 – 24LC256-I/P
 IC2 – PIRA32 Microcontroller
 IC3 – MAX232
 IC4 – LM567
 IC5 – TLC272
 IC6 – 7805
 IC7 – PCF8563T smd

D1, D2 – 1N4001
 D3, D4 – LED 5mm
 D5, D6 – 1N4148 smd
 Y1 – 4.332 MHz crystal
 Y2 – 32.768 kHz crystal
 L1 – 09P-331K
 L2 – 09P-152J
 RE1 – signal relay
 J4 – CANON 9M
 J5, J6 – BNC

R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R17, R29, R30 – 2k
 R14, R15, R19, R20, R26, R31, R32, R33 – 10k
 R16, R21, R24 – 33k
 R18, R22 – 15k
 R23 – 4k7
 R25 – 100R/91R
 R27 – trimmer 1k
 R28 – trimmer 10k
 RN1 – 3x 1k resistor network
 RN2 – 4x 1k resistor network

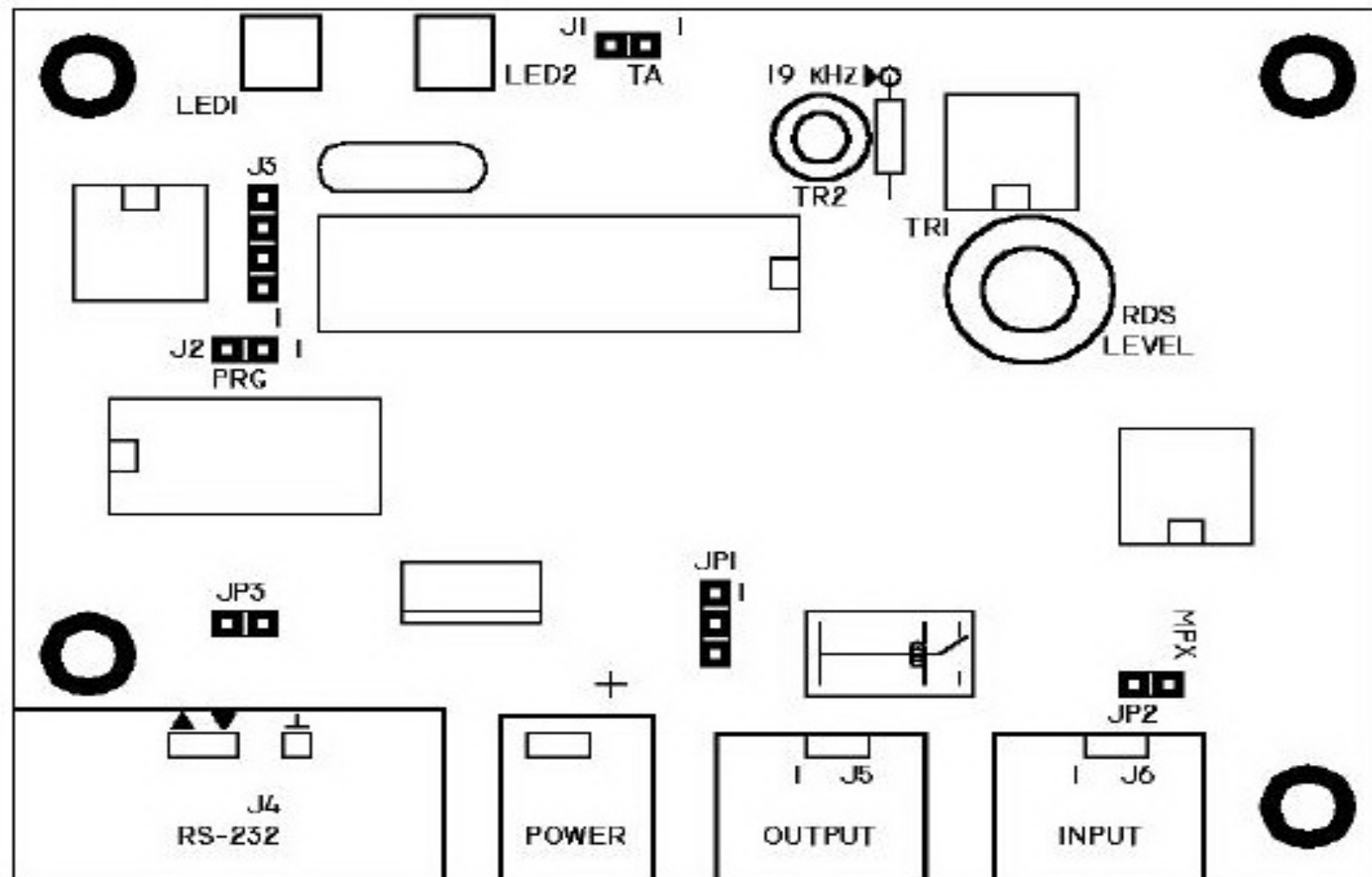
C1, C2, C3, C4 – 1u/50V (E)
 C5, C10 – 100u/25V (E)
 C6, C11, C12, C18, C19, C20, C24, C32 – 100n (C)
 C7, C8 – 10u/35V (E)
 C9, C33 – 100u/10V (E)
 C13, C14, C26, C30 – 22p (C)
 C15, C16, C25 – 4n7 (P)
 C17 – 22n (5%, P)
 C21 – 3n3 (P)
 C22 – 220n (P)
 C23, C29 – 1n (C)
 C27 – 47n (5%, P)
 C28 – 330p (C)
 C30 – 10p/12p (C) smd
 C31 – 4u7/3u3 (P)
 BT1 – CR2032 vertical

102 = 1n	331 = 330p
104 = 100n	332 = 3n3
223 = 22n	472 = 4n7
224 = 220n	473 = 47n

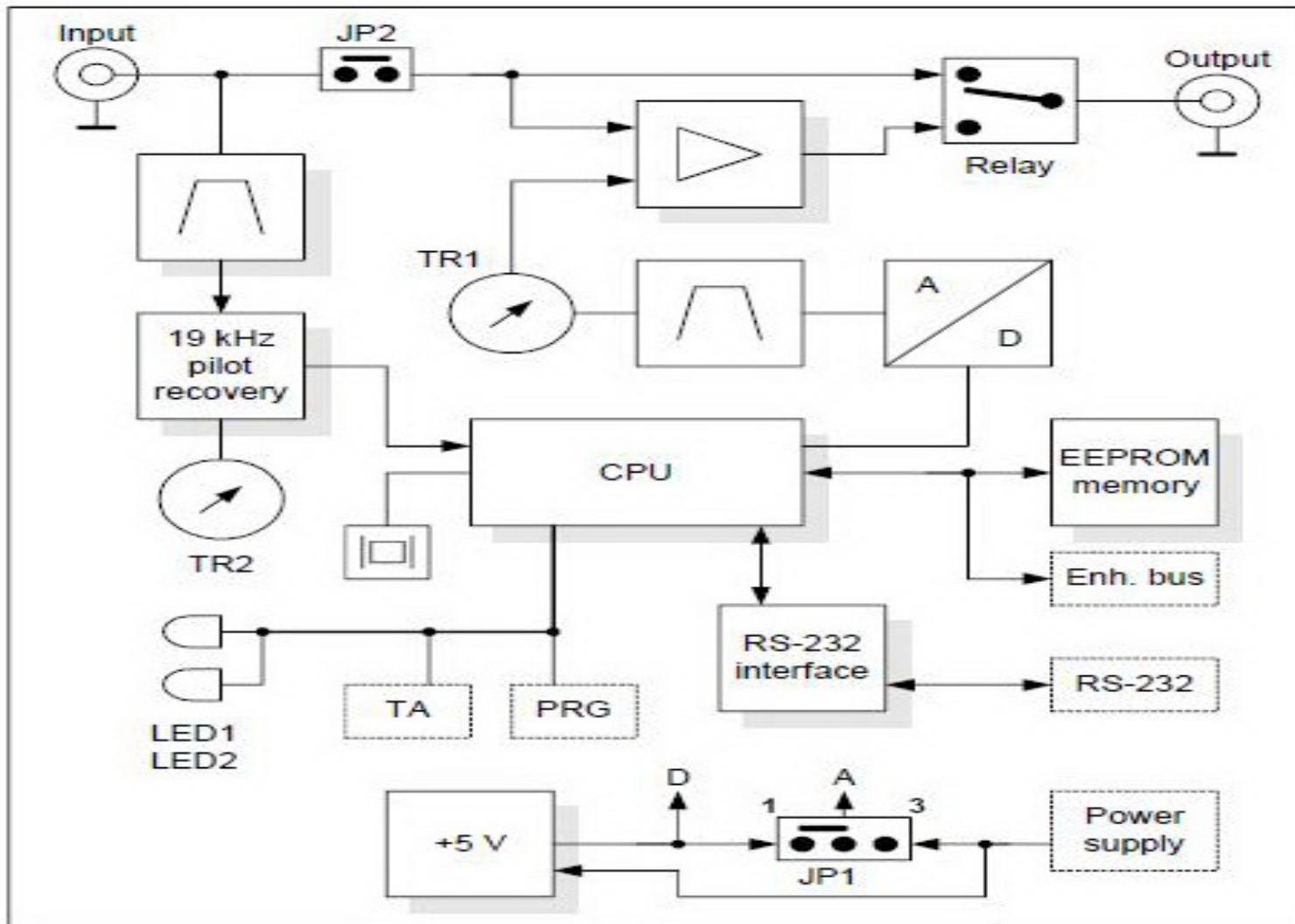


Physical Description

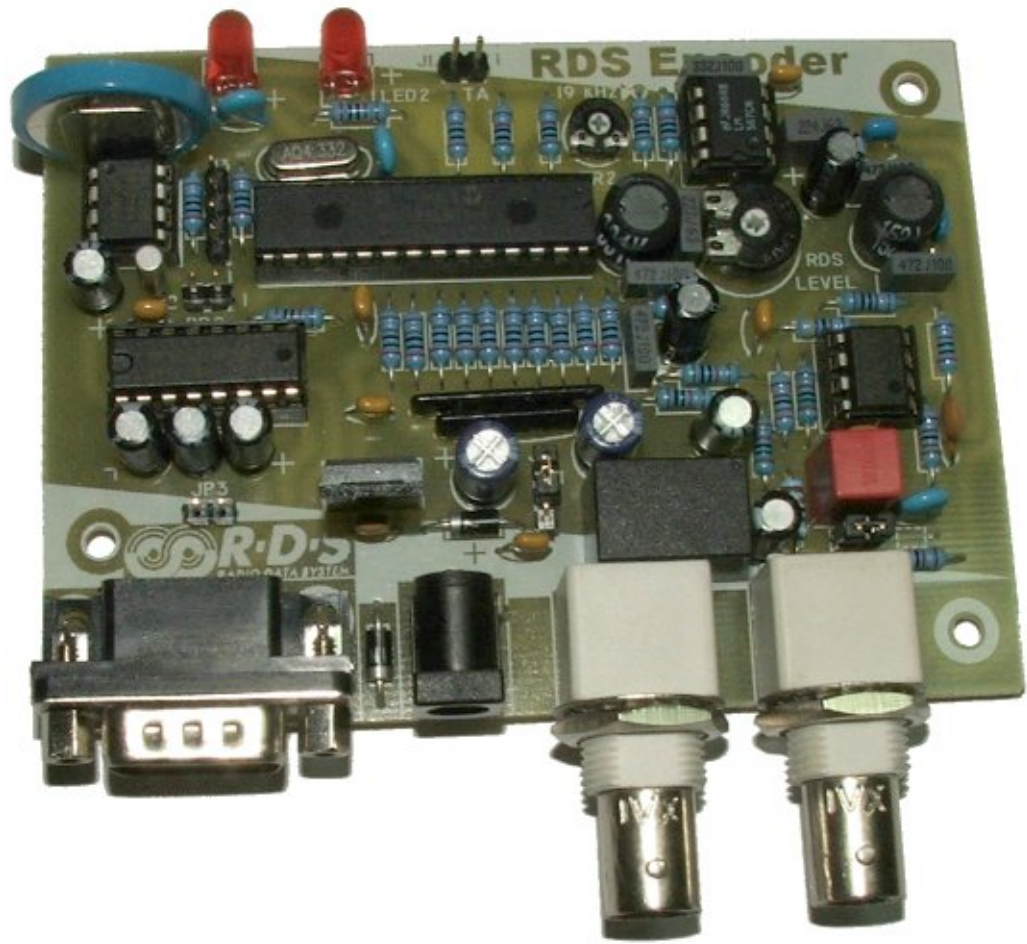
Composition



Block Diagram



RDS Encoder Circuit



The box of the RDS encoder from front and from the back

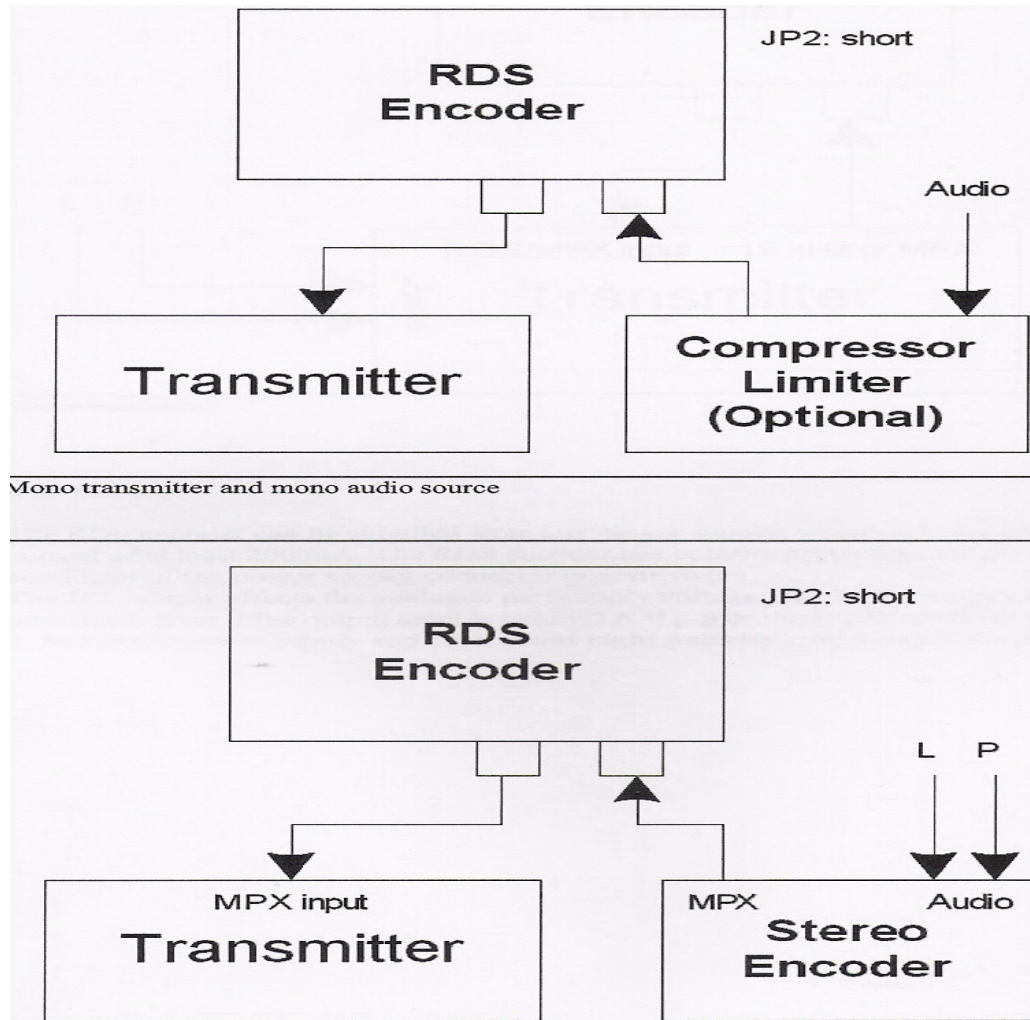


How to connect RDS Encoder to PC?

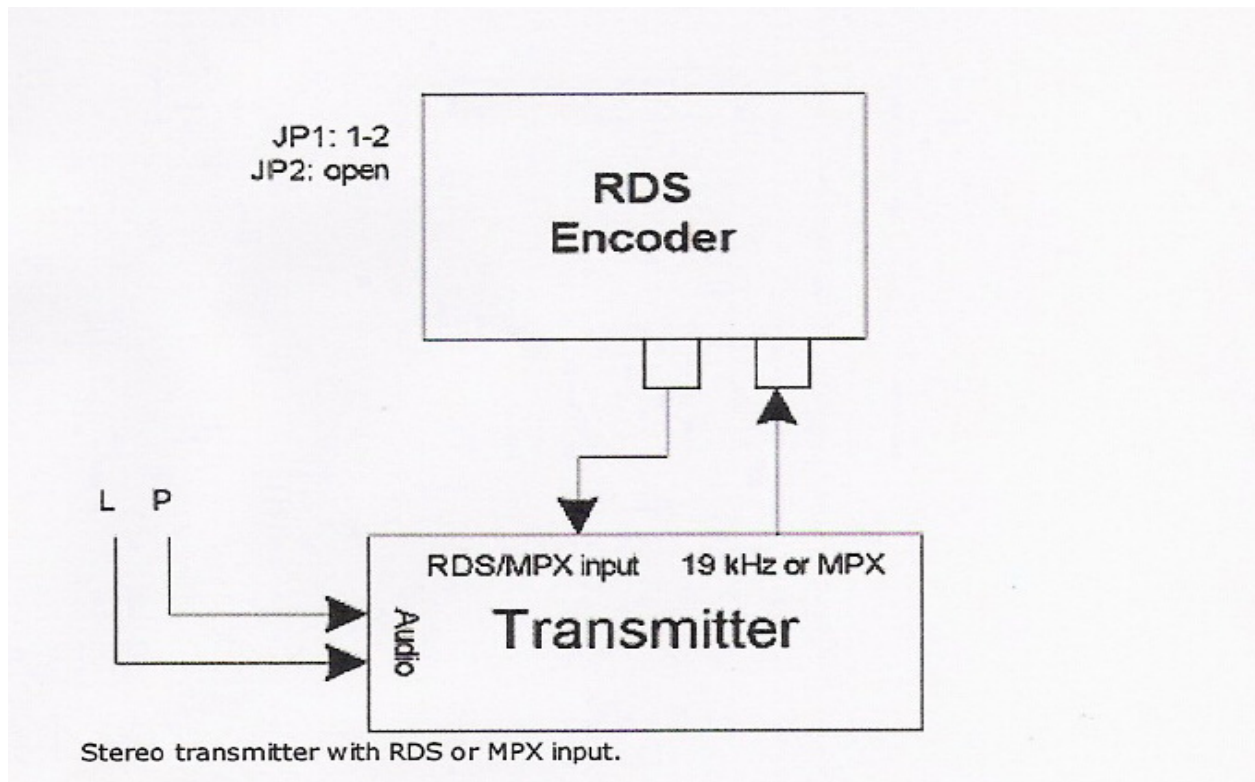
The RDS encoder is connected directly to PC via standard serial lap-link cable terminated by CANON D-SUB female plugs.

We use our program to control the RDS. In fact the Magic RDS works as a Demo version software for our RDS encoder.

How to connect RDS Encoder to transmitter?



Alternative connection for RDS Encoder

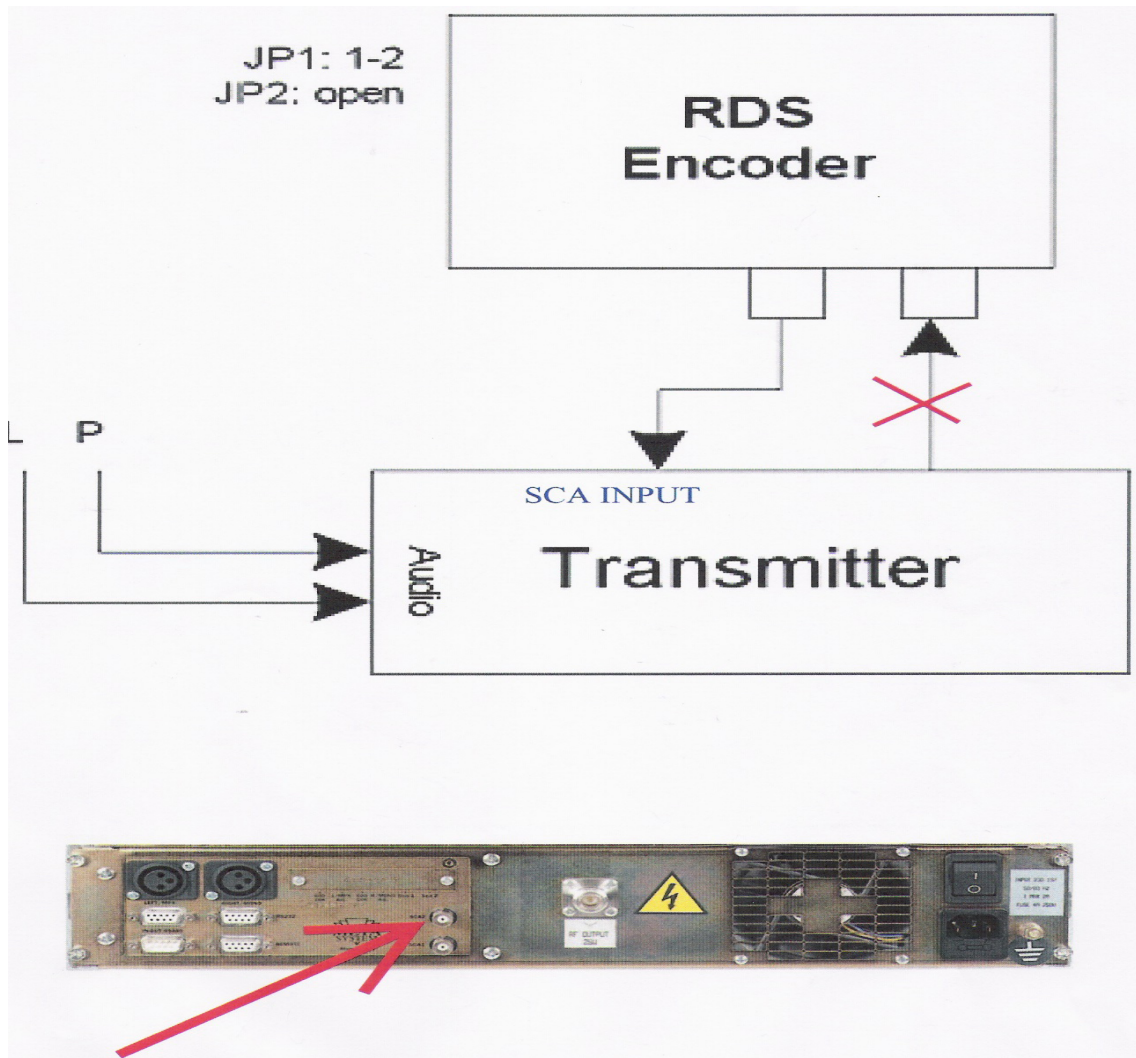


RDS Connection in Radio Campus Duisburg-Essen University

The output of the RDS Encoder should be connected to the SCA2(sub-carrier2 input level adjustment) of the transmitter in order to transmit the Program service identification which is Campus FM.

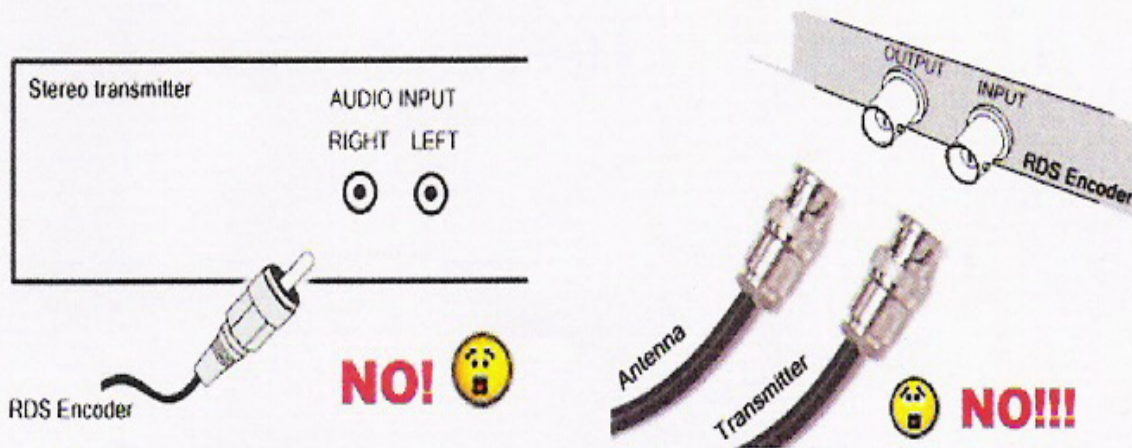
**Our Transmitter name is Cte broadcast 25
W FM Transmitter TX25 PLUS.**

How to connect RDS Encoder to a Transmitter in University?



Attention before connection

Never to do...

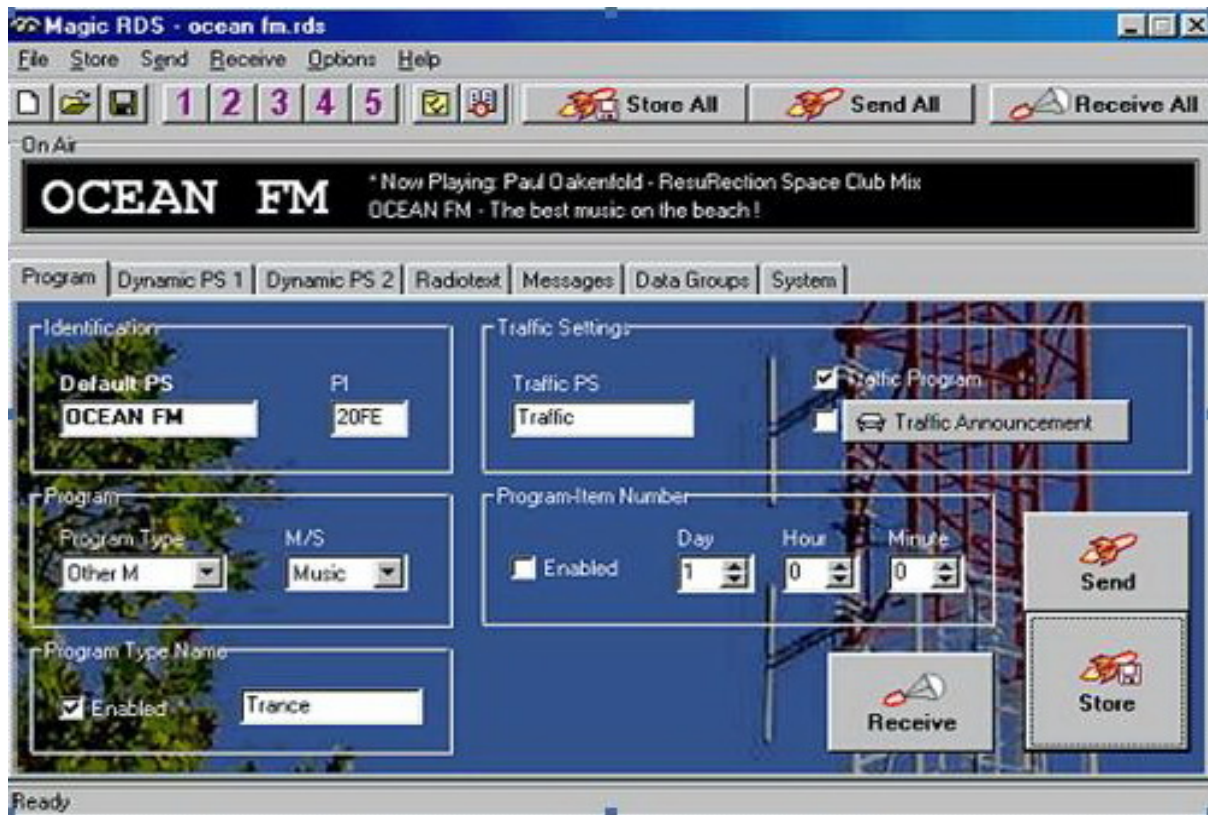


Processing RDS signal in the stereo encoder may affect spectral purity and data error rate or it will simply not work.

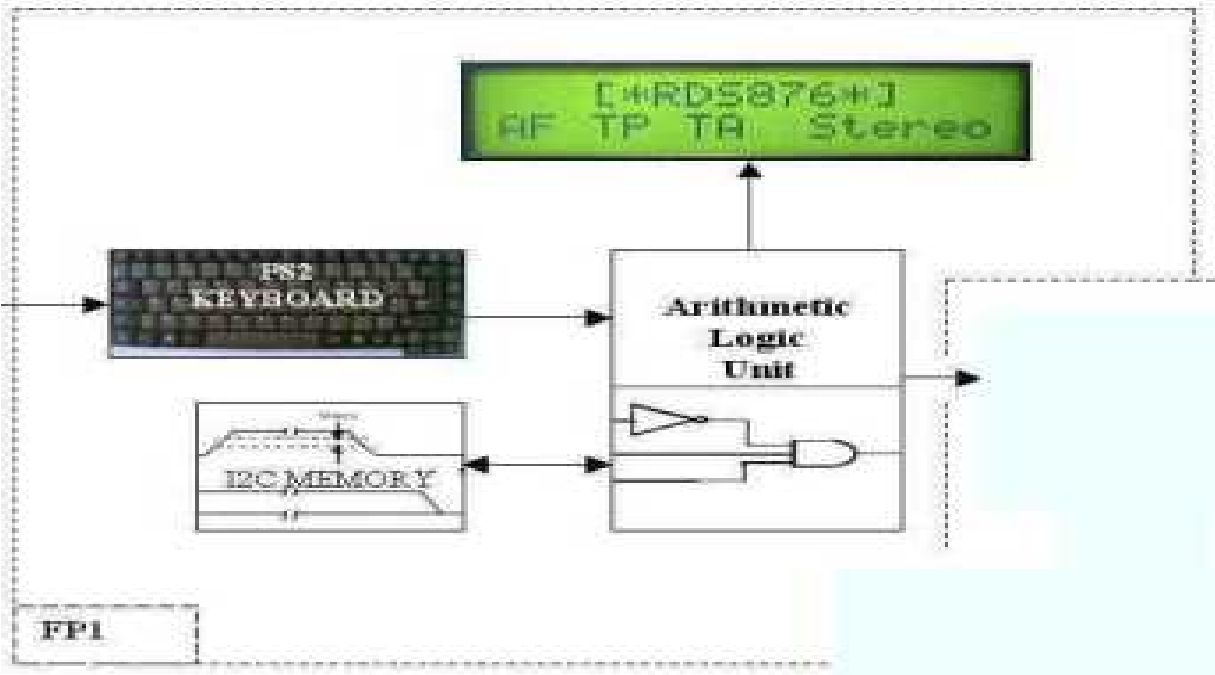
Don't use audio inputs in this case, **use RDS, MPX or SCA input**, if provided. See also F.A.Q.

Never connect the transmitter/exciter output to the RDS encoder input. This will really not work. You may damage the devices easily.

The interface of software



RDS Encoder Description

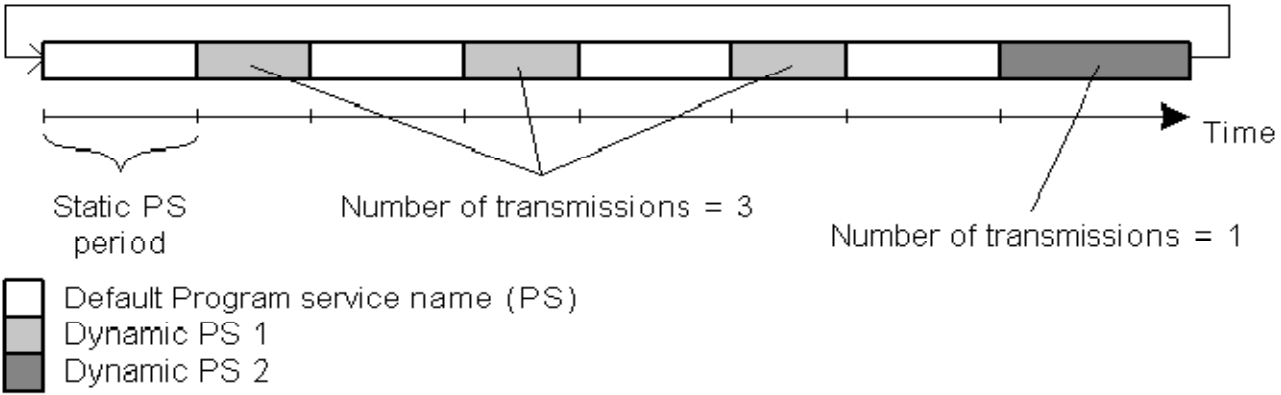


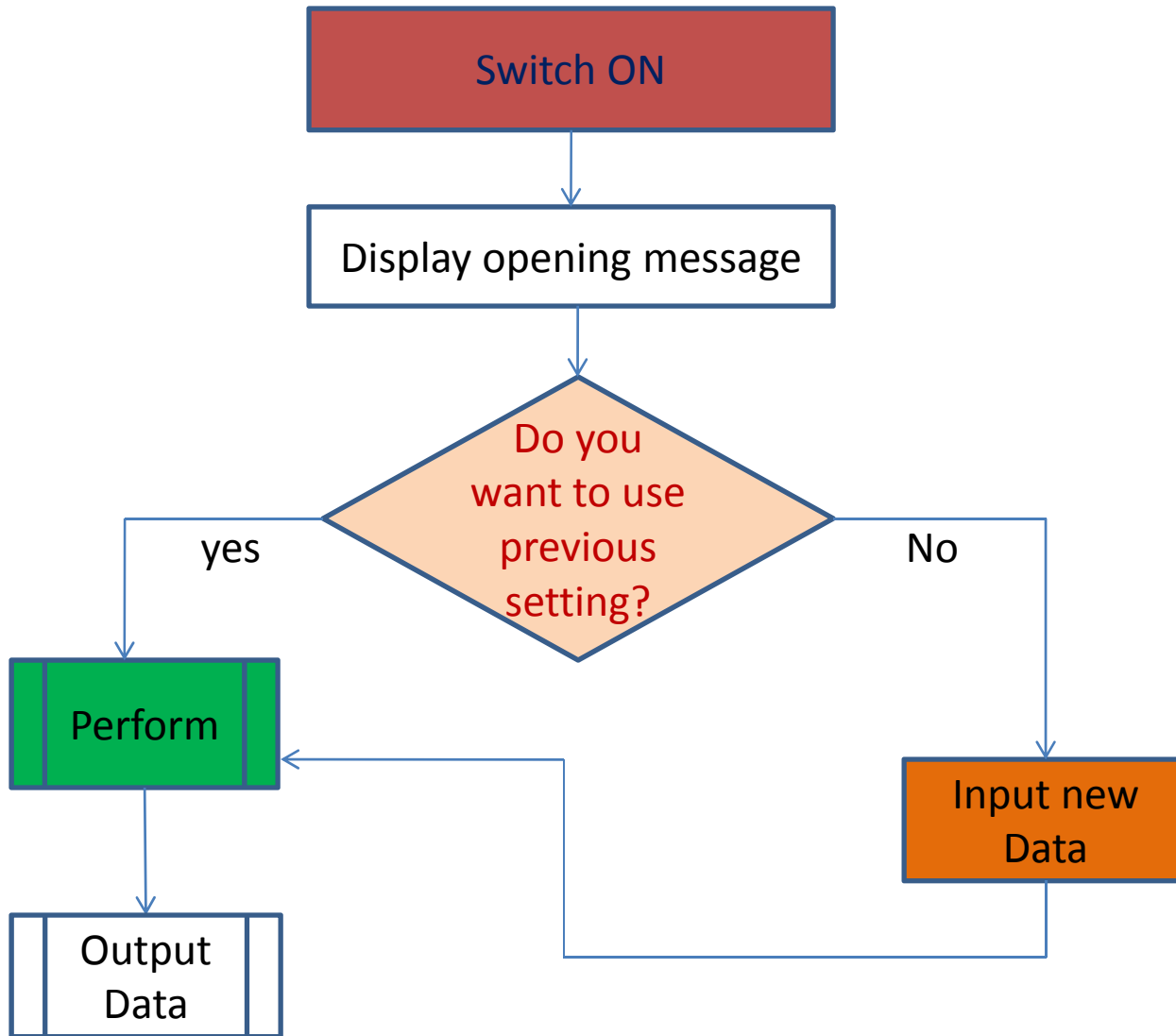
Interface of our Program

The screenshot shows a Windows-style window titled "Form1". At the top, there is a text field containing "Radiotext 1 *** Radiotext 1 *** Radiotext 1". Below this, there are three main sections: "PC Port" with radio buttons for COM1 through COM8 (COM1 is selected), "PC Port Speed" with radio buttons for 1200, 2400, 4800, and 9600 (2400 is selected), and "Default PS:" with a text field containing "Hello". To the right of the "Default PS:" field are two buttons: "Send" and "Store". Below these is a "Read" button. The status bar at the bottom left of the window displays "Ready".

The program has been written in Delphi and has been attached with the software in a CD to the documentation. In our case here in Duisburg-Essen University we gave for our Default PS the CAMPUSFM as program service Identification which can be received in very high frequency of 104.50 from Duisburg and 105.60 from Essen.

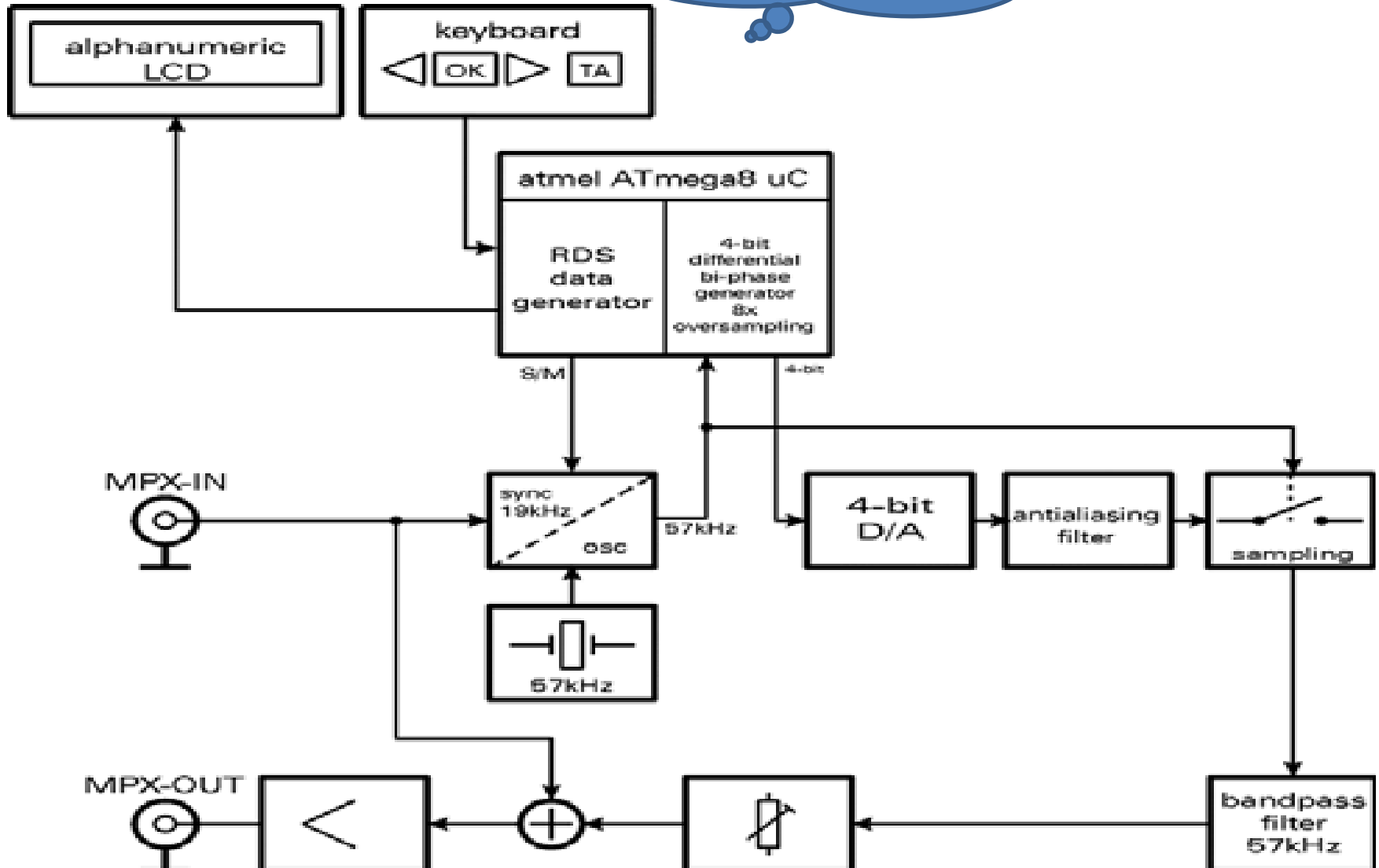
Message Format and addressing for PS



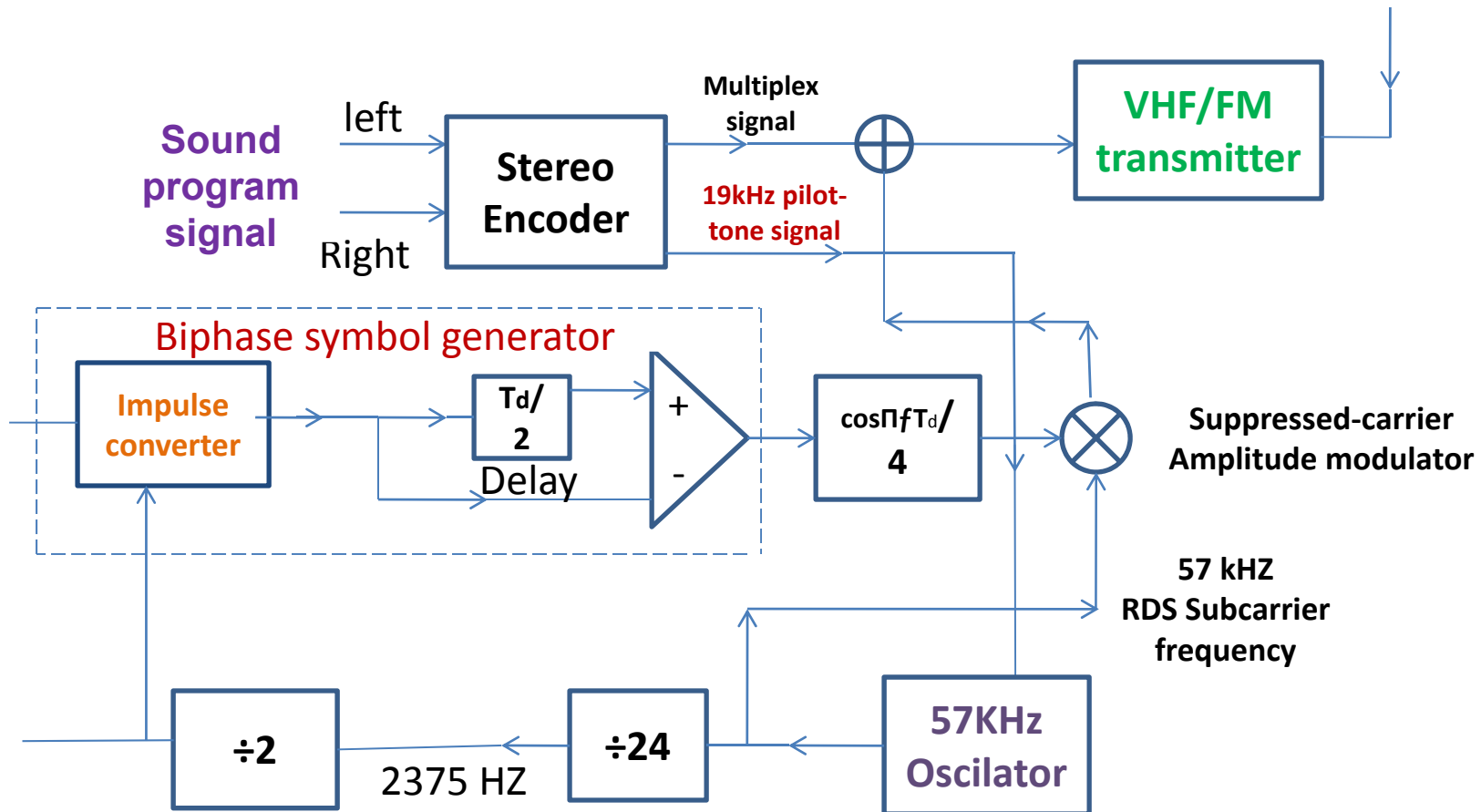


Flow Chart of Our Program

RDS Encoder Block diagram Concept



Modulation characteristics of the data channel

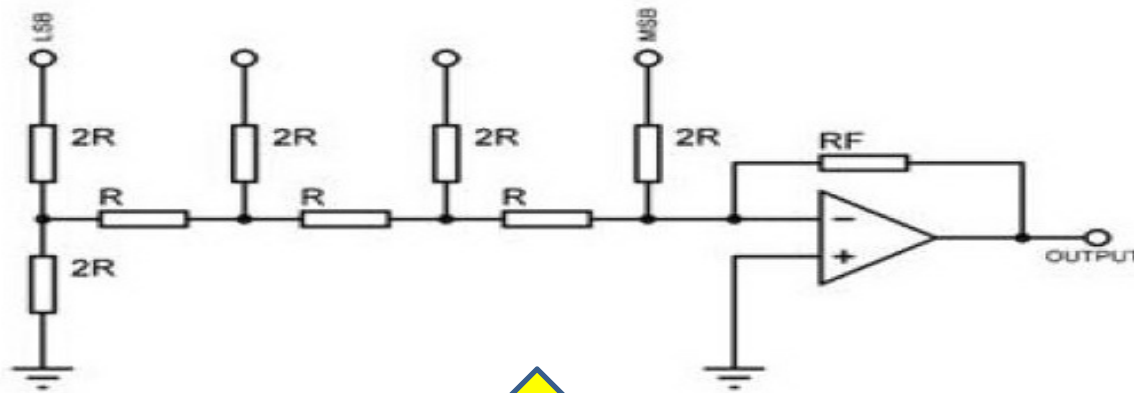


The power of the data signal around the 57 kHz sub-carrier is minimized by coding each source data bit as a binary-phase symbol.

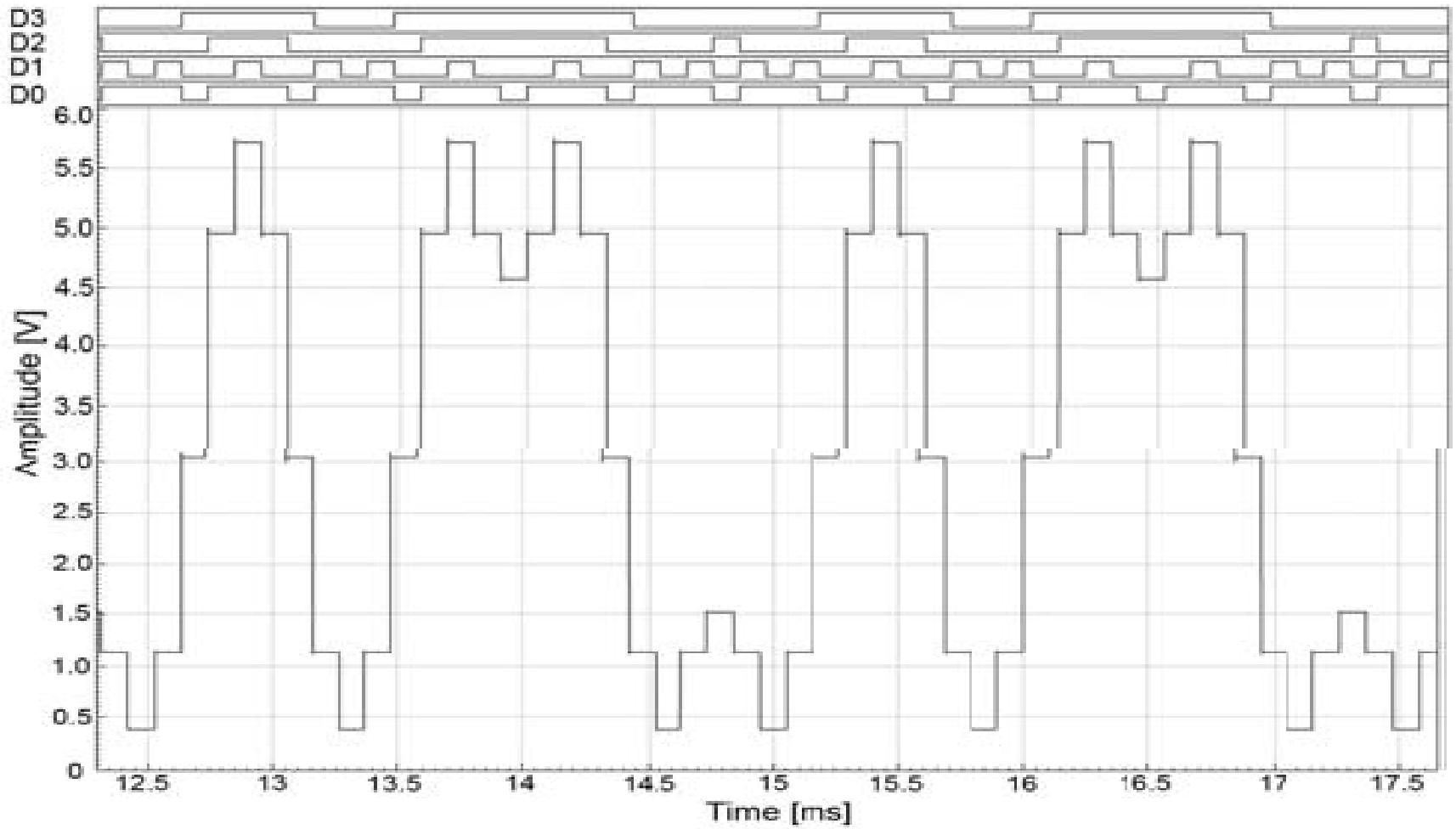
4-Bit D/A(Digital to Analog) Converter

The 4-bit D/A converter is done with a R-2R ladder network as shown in figure below and produces the output voltage according to V_{out} , where the D 's take the value 0 or 1 and $V_{ref} = 5\text{ v}$.

$$V_{out} = \frac{RF}{R} \left(\frac{D_3}{2} + \frac{D_2}{4} + \frac{D_1}{8} + \frac{D_0}{16} \right) \cdot V_{ref}$$



R-2R ladder network.



Digital RDS signal

Anti-aliasing Filter Frequency response

Digitally generated eight time over sampled RDS signal after D/A converter and related 4-bit bus states are shown in Figure below. The anti-aliasing filter is needed to suppress the overtones.

The anti-aliasing filter is needed to suppress the overtones. It can be seen that the first overtone is suppressed with approximately 40 dB.

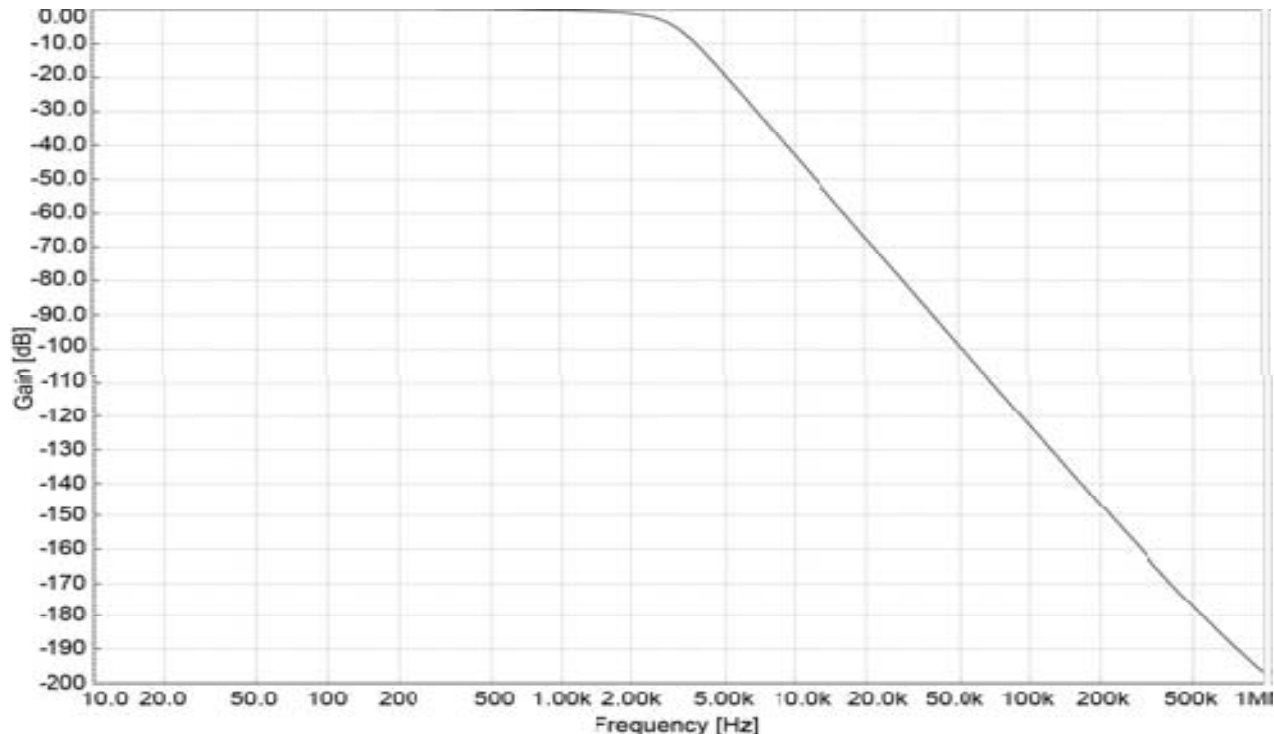
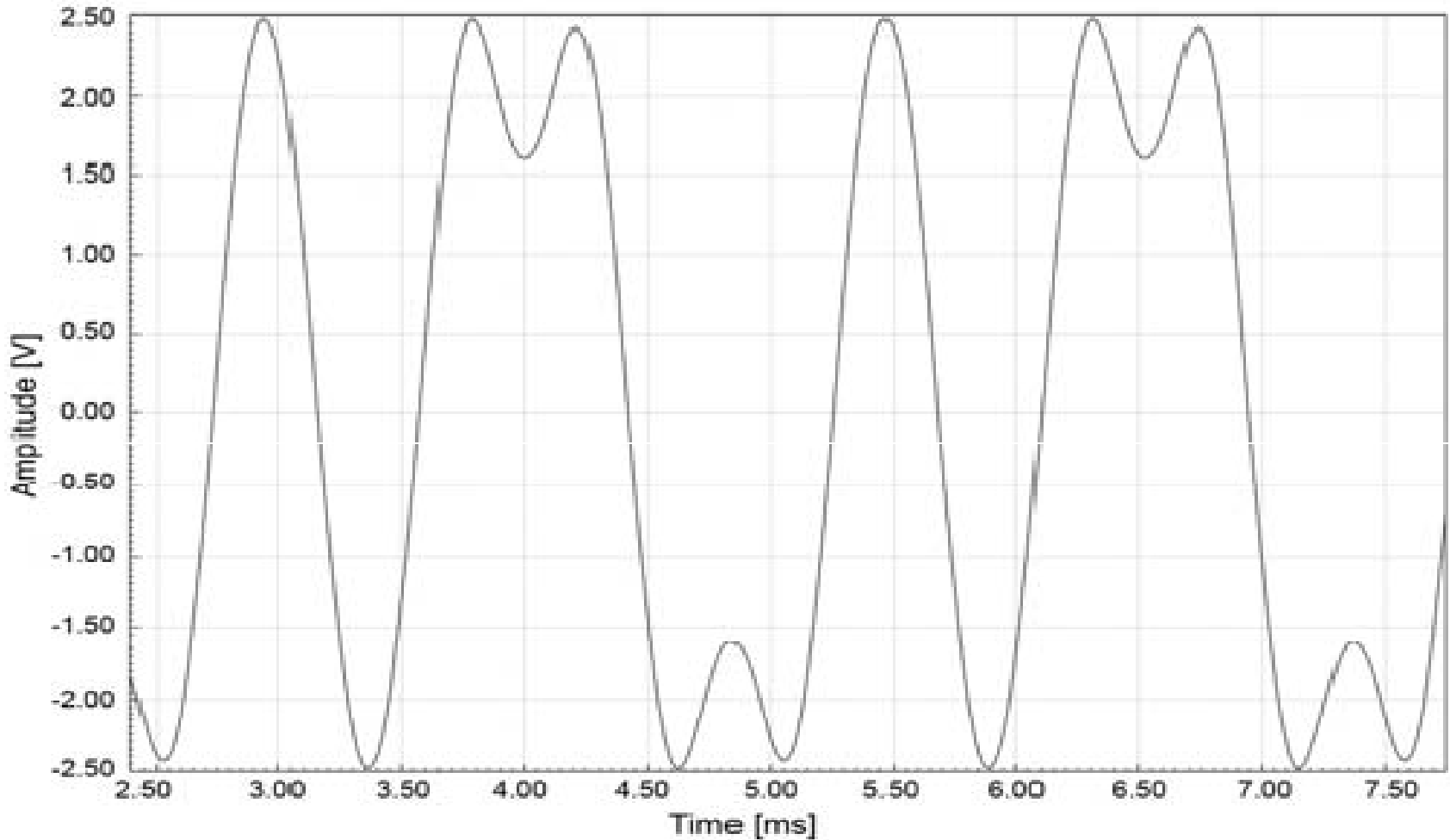
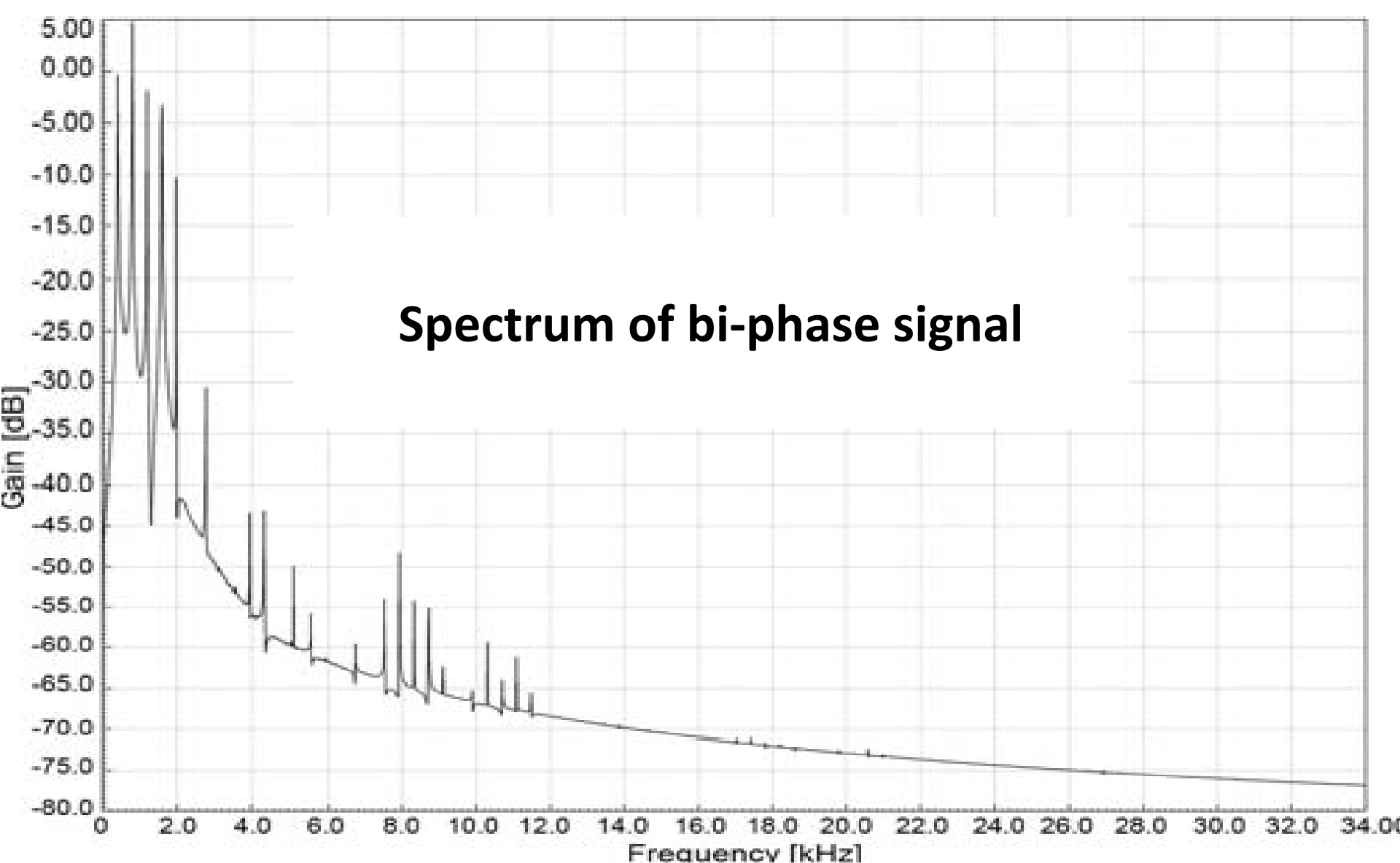


Figure Anti-aliasing filter frequency response



Baseband RDS bi-phase signal

After RDS signal passes through the filter, only baseband bi-phase signal remains as shown in Figure below.



Spectrum of bi-phase signal

Maximum baseband frequency is 2.4 kHz, and all the frequencies above 2.4 kHz are suppressed over 30 dB

$$H_T(f) = \begin{cases} \cos \frac{\pi f t_d}{4} & \text{if } 0 \leq f \leq 2/t_d \\ 0 & \text{if } f > 2/t_d \end{cases}$$



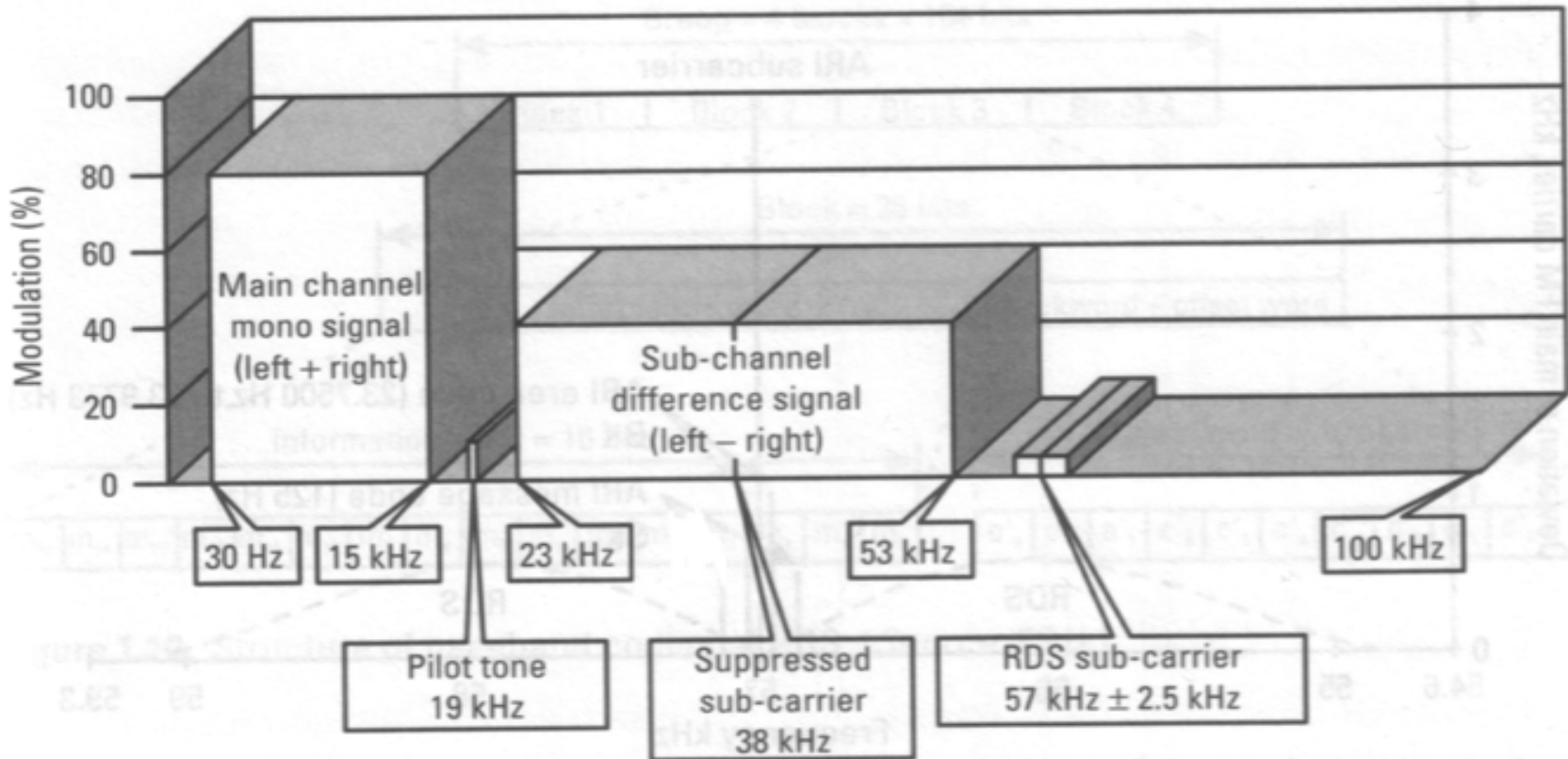
These impulse-pairs are shaped by a filter $H_T(f)$, to give the required band-limited spectrum

The basic clock frequency is obtained by dividing the transmitted RDS sub-carrier frequency (57 kHz) by 48. Consequently, the basic data-rate of the system is 1187.5 bits/second.

This method of modulation may alternatively be thought of as a form of two-phase phase-shift-keying (PSK) with a **phase deviation of ± 90 degree**.

The Radio Data System is intended for application to VHF/FM sound broadcasting transmitters in the range 87.5 to 108.0 MHz, which carry stereophonic (pilot-tone system) or monophonic sound broadcasts.

FM signal spectrum

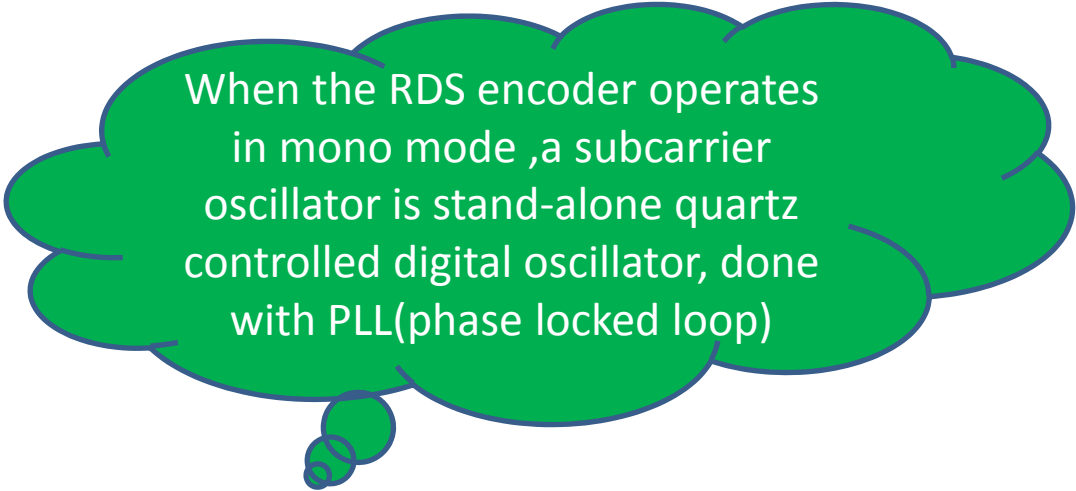


The data signals are carried on a subcarrier which is added to the stereo multiplex signal (or monophonic signal as appropriate) at the input to the VHF/FM transmitter.

We use the 19 kHz pilot synchronization **only** with the event that we transmit in **stereo**.

During stereo broadcasts, the subcarrier will be locked to **the 19 kHz pilot-tone**.

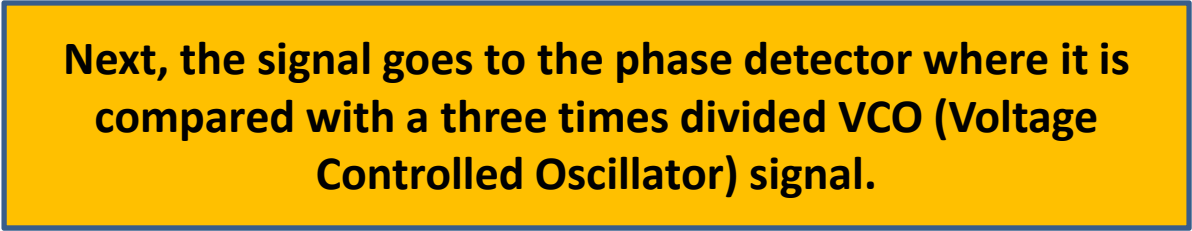
The tolerance on the frequency of the 19 kHz pilot tone is ± 2 Hz ; therefore the tolerance for the frequency of the subcarrier during stereo broadcast is ± 6 Hz.



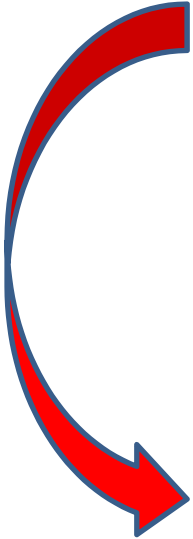
When the RDS encoder operates in mono mode ,a subcarrier oscillator is stand-alone quartz controlled digital oscillator, done with PLL(phase locked loop)



First, the 19 kHz band pass filter is needed to isolate 19 kHz stereo pilot-tone from the MPX signal.

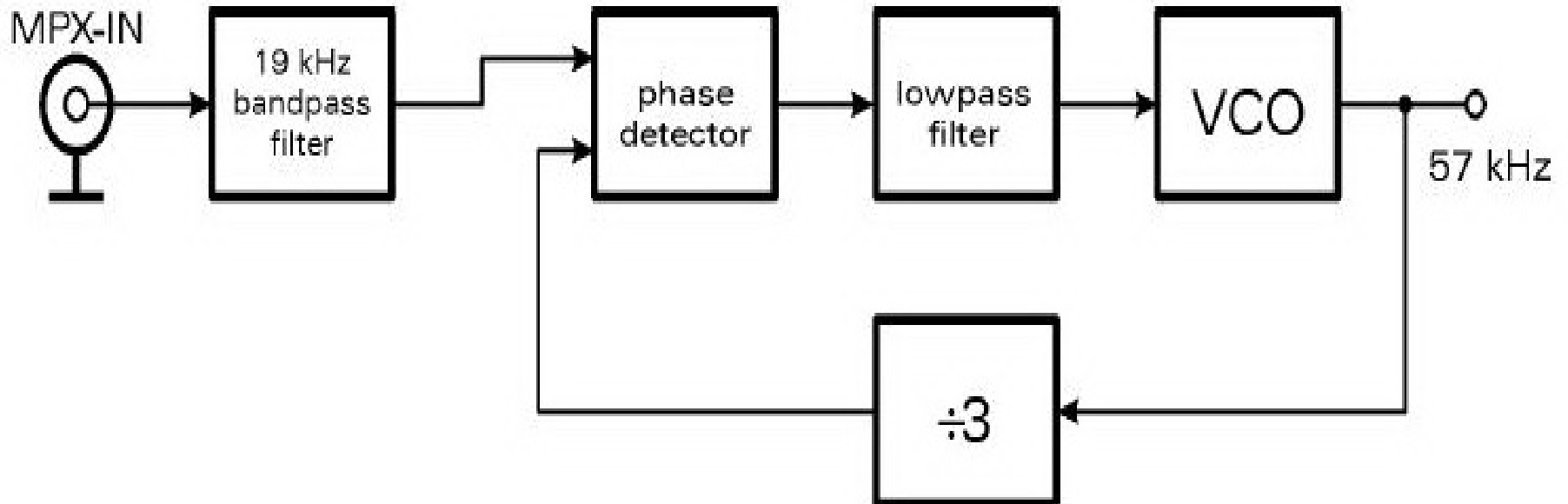


Next, the signal goes to the phase detector where it is compared with a three times divided VCO (Voltage Controlled Oscillator) signal.



PLL System

Figure shows the waveform of the 19 kHz input and 57 kHz output of the PLL circuit



DSB-SC Modulation

Double side band - suppressed carrier modulation method is described as

$$u_{\text{DSB-SC}}(t) = u_m(t) \cdot \cos(\omega_0 t)$$

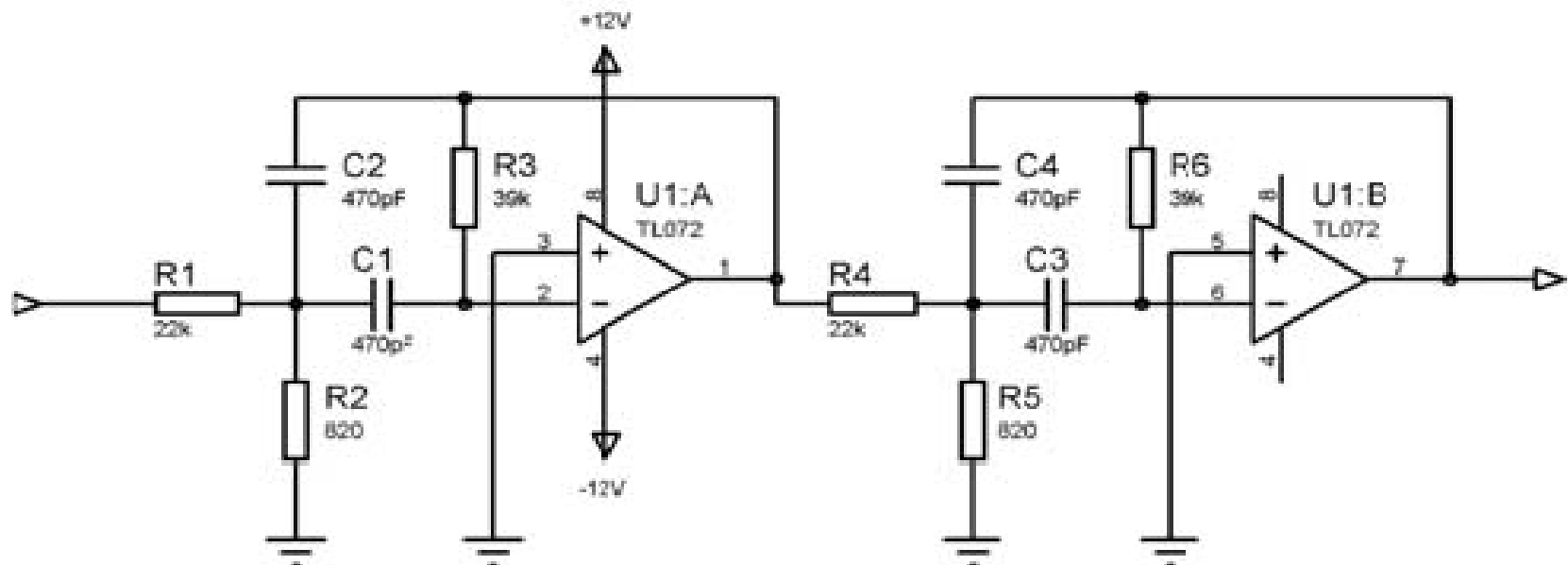
where $u_m(t)$ is the modulation signal, and ω_0 is the circular frequency of the modulated carrier. If $u_m(t)$ is a harmonious function such as

$$u_m(t) = A \cos(\omega_m t)$$

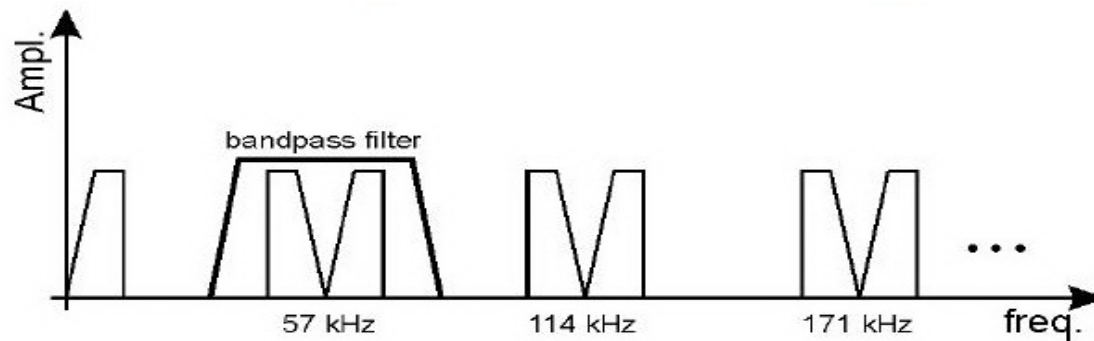
Finally we can see that the DSB-SC modulation method have an upper side band ($\omega_0 + \omega_m$) and a lower side band ($\omega_0 - \omega_m$) around the suppressed carrier.

$$u_{\text{DSB-SC}}(t) = \frac{A}{2} \cos[(\omega_0 + \omega_m) \cdot t] + \frac{A}{2} \cos[(\omega_0 - \omega_m) \cdot t]$$

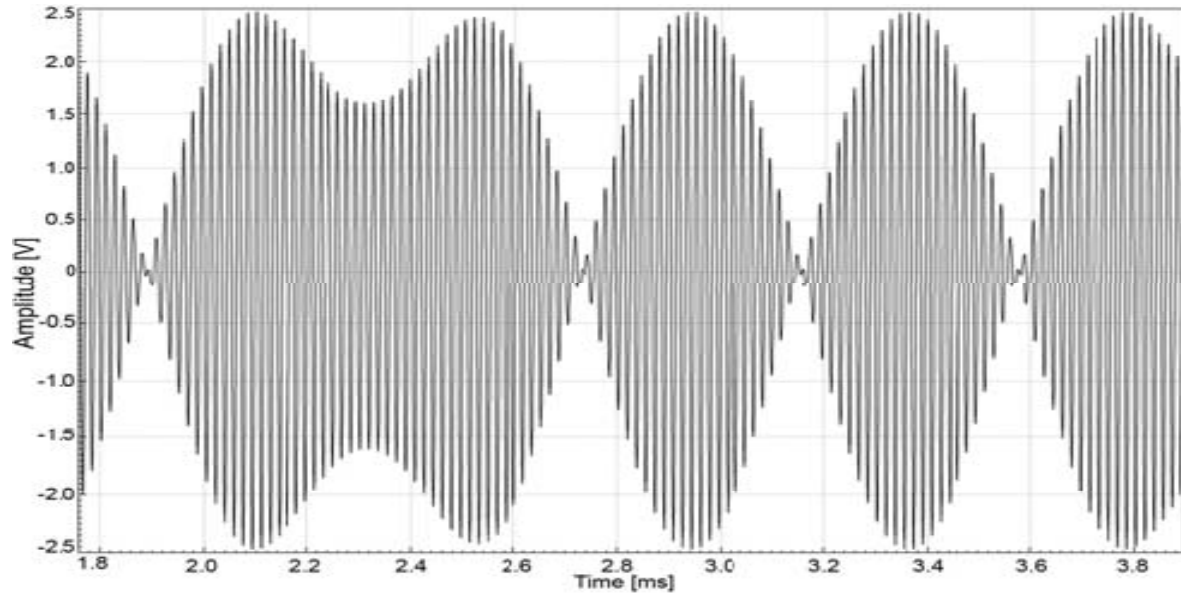
DSB-SC realization in our case is obtained by sampling the baseband bi-phase signal with a 57 kHz clock and filtering around 57 kHz with a band pass filter. The band pass filter is fourth order active filter (type Butterworth) shown in Figure



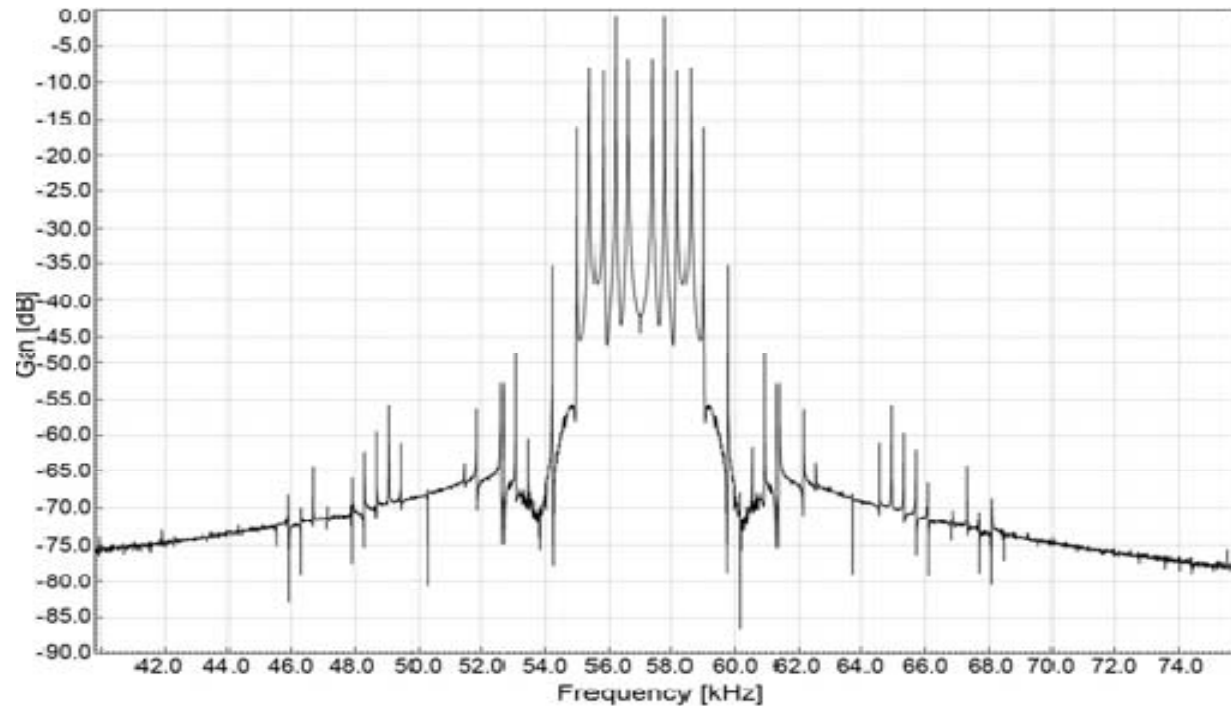
The whole principle of DSB-SC modulation with this method is shown in Figure below. After the DSB-SC realization method, a RDS signal obtains this figure below.



DSB-SC carrier spectrum is shown



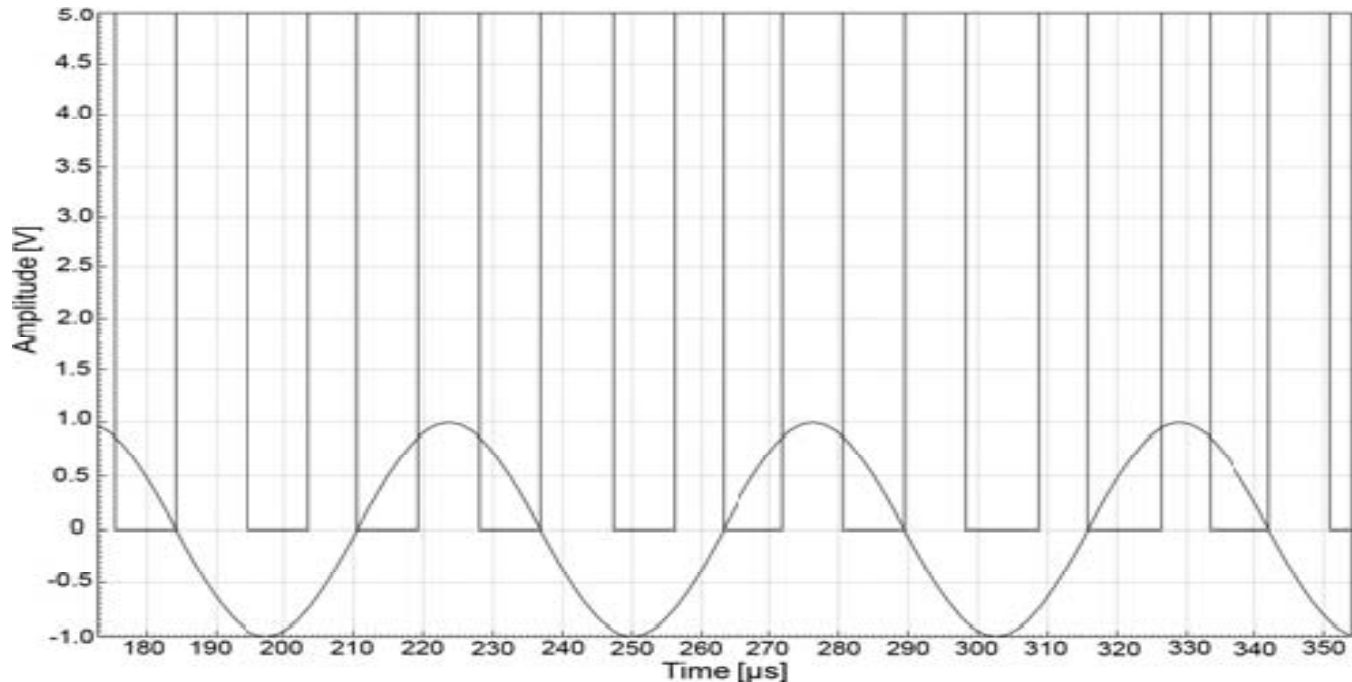
DSB-SC modulated RDS signal.



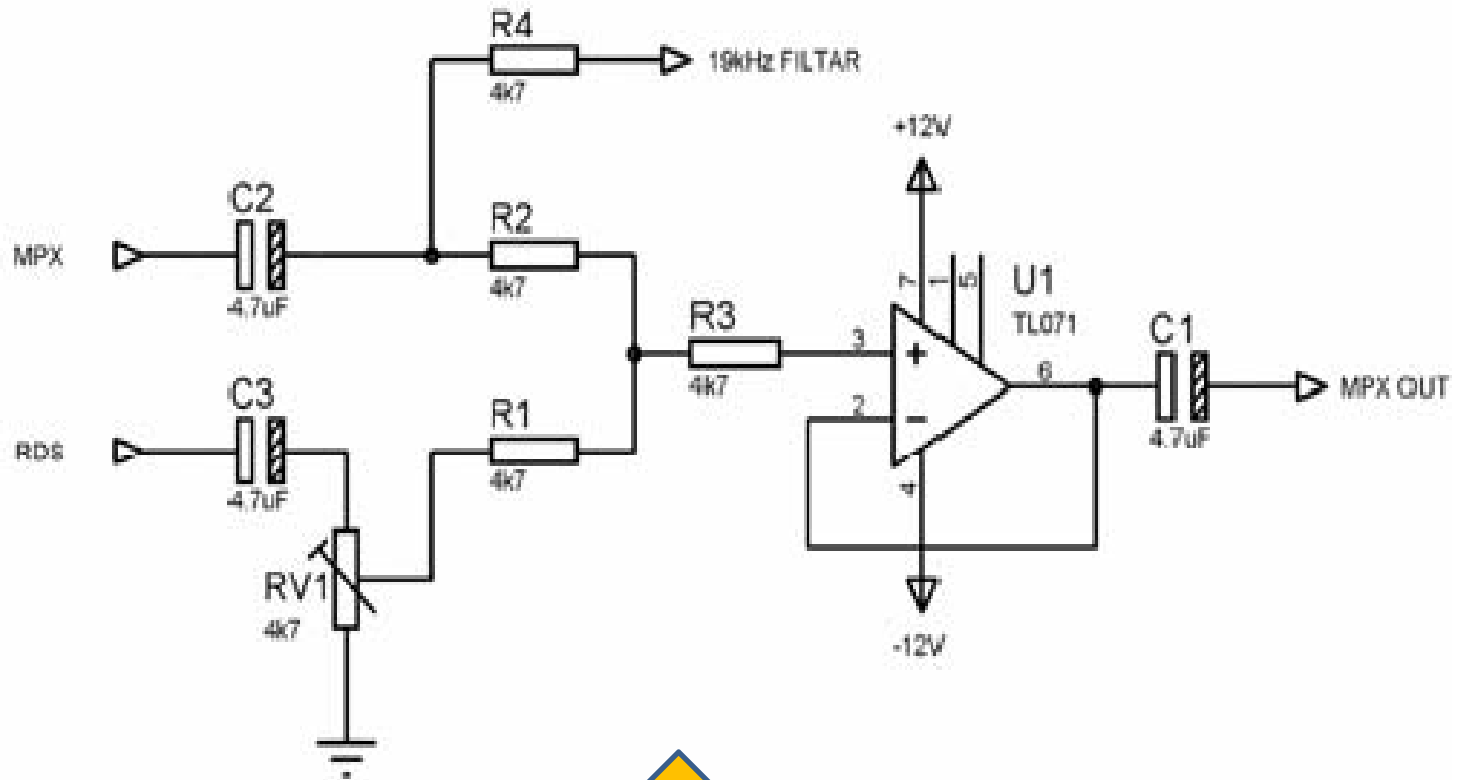
RDS signal spectrum

Summary Block

The last issue is to sum RDS signal with a FM composite stereo multiplex or mono signal depending on the input signal. We can use a variable resistor which is used to set the RDS signal level. After the summing, buffer amplifier outputs the MPX and RDS signal together as

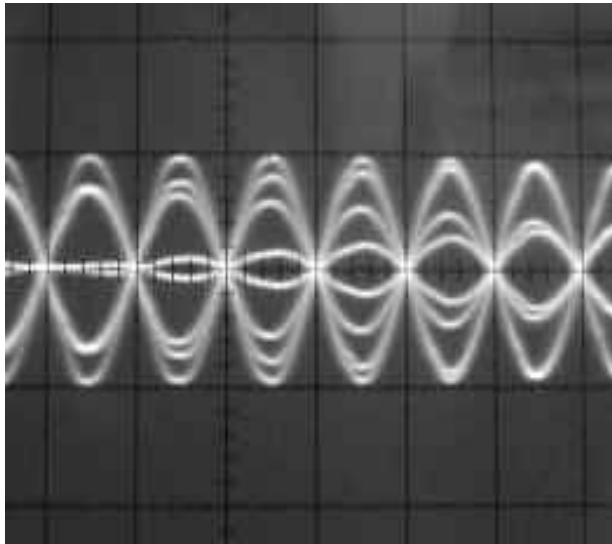


↑
PLL signals

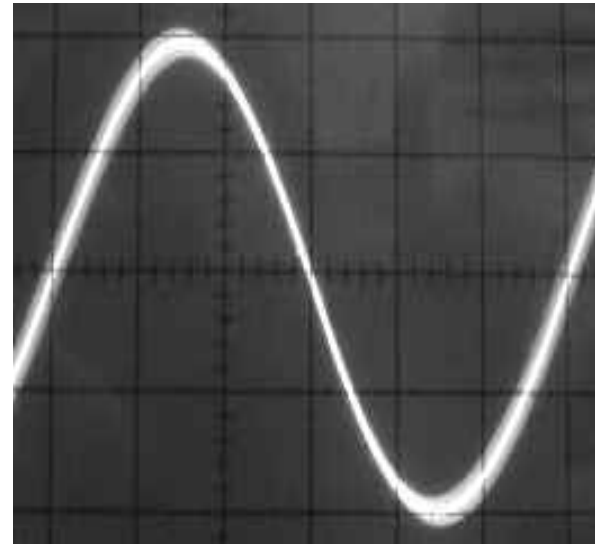


Realization of summation block

Measurement of the signals with Oscilloscope

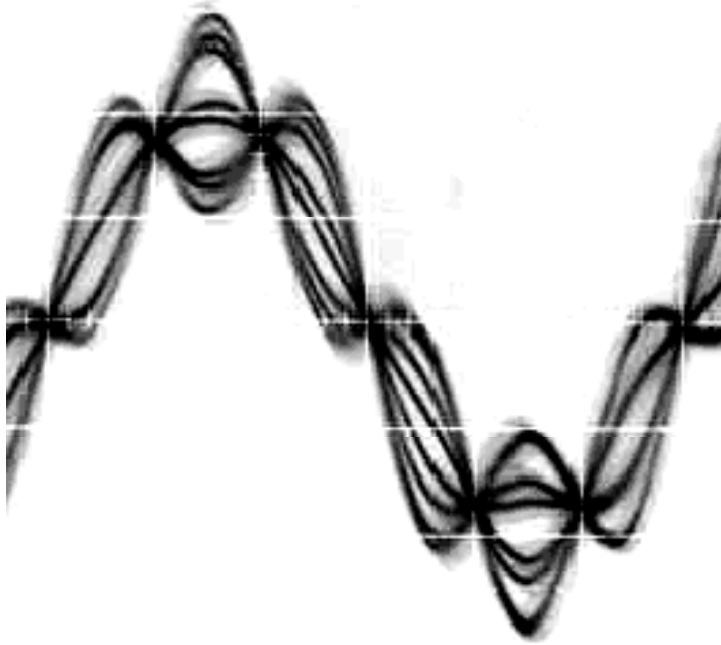


RDS signal

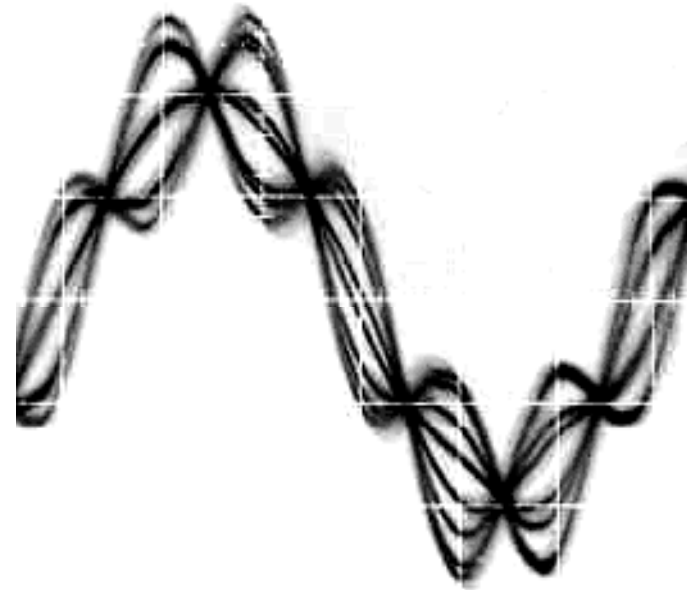


Pilot tone 19 kHz

Figures show the appearance of RDS signal, **pilot tone** and a RDS signal added to the pilot tone.



**Pilot and RDS in-phase
(0 degrees phase shift)**



**Pilot and RDS in quadratic
(90 degrees phase shift)**

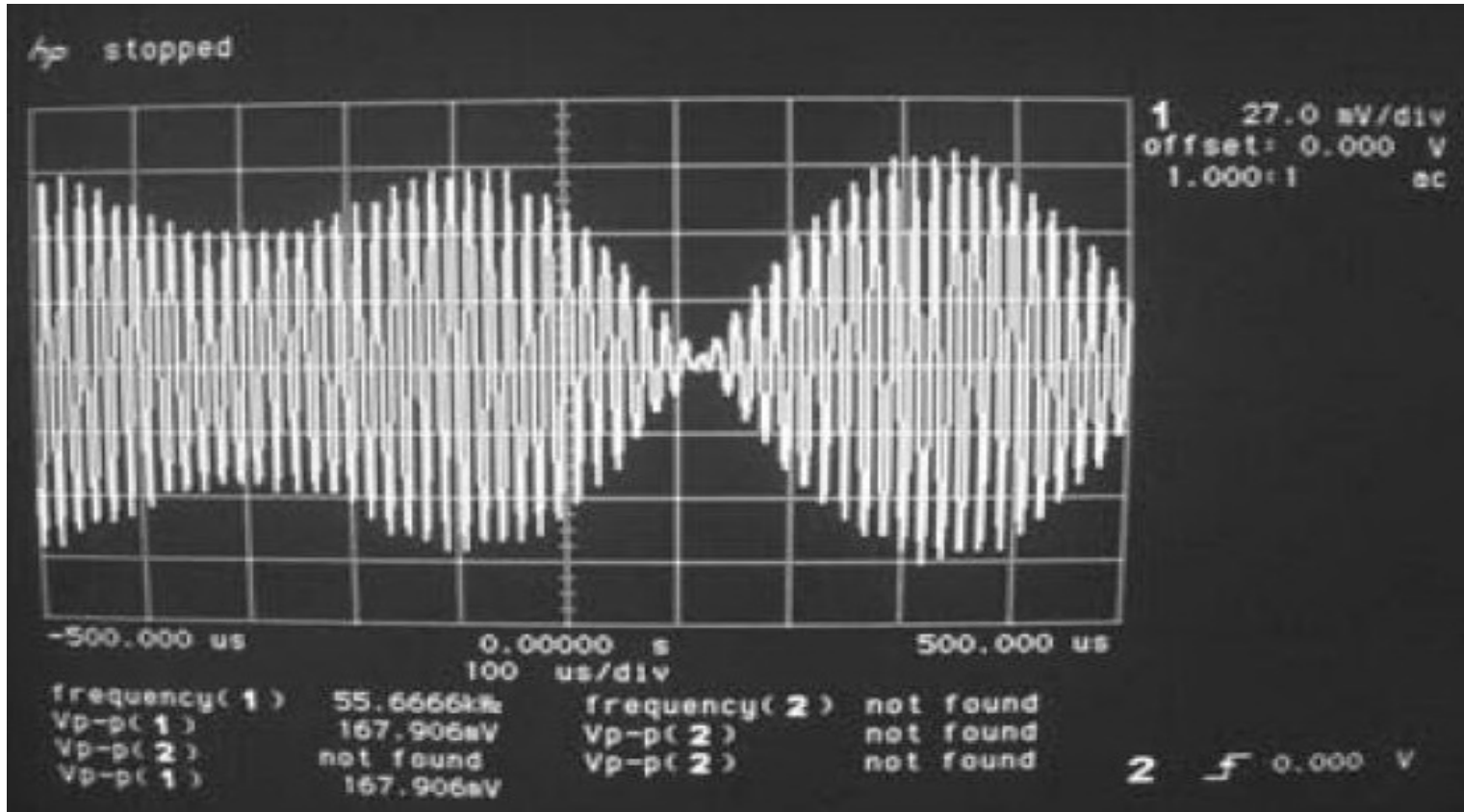
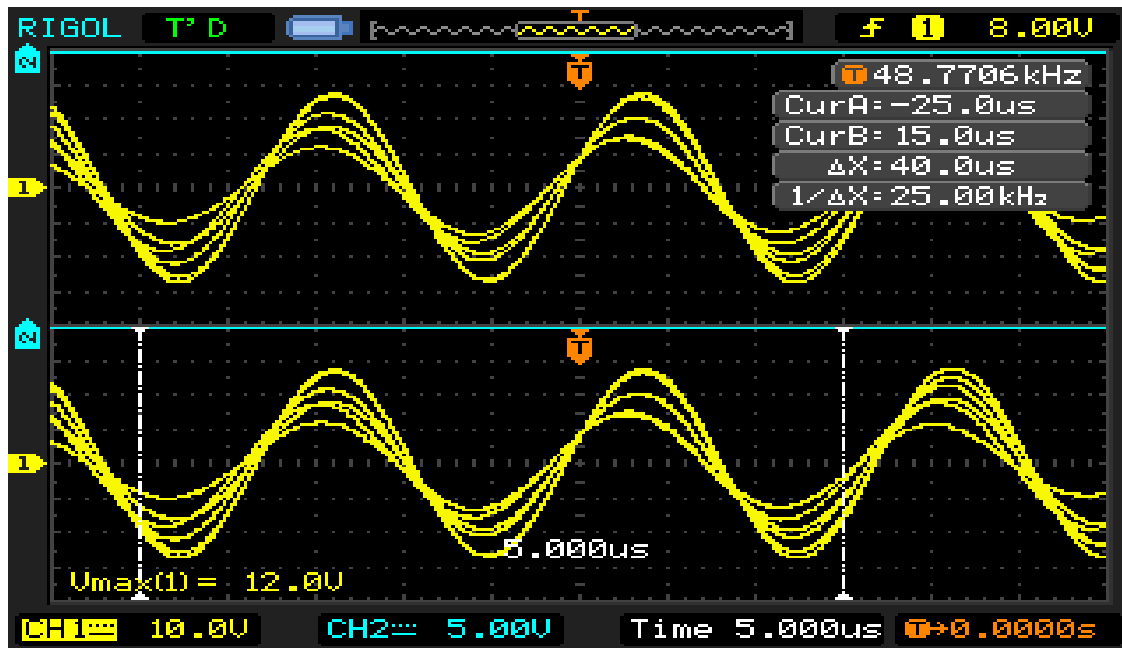
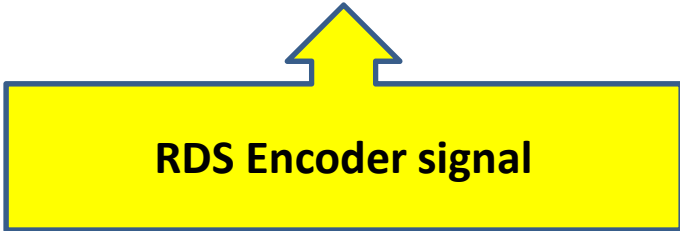
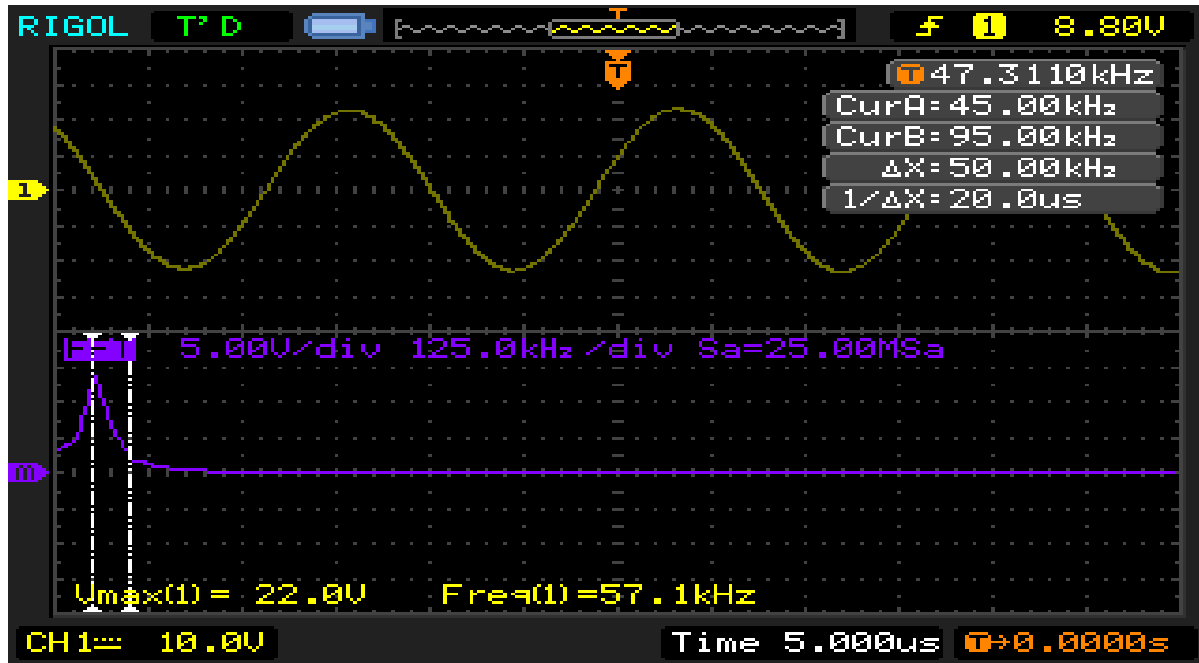
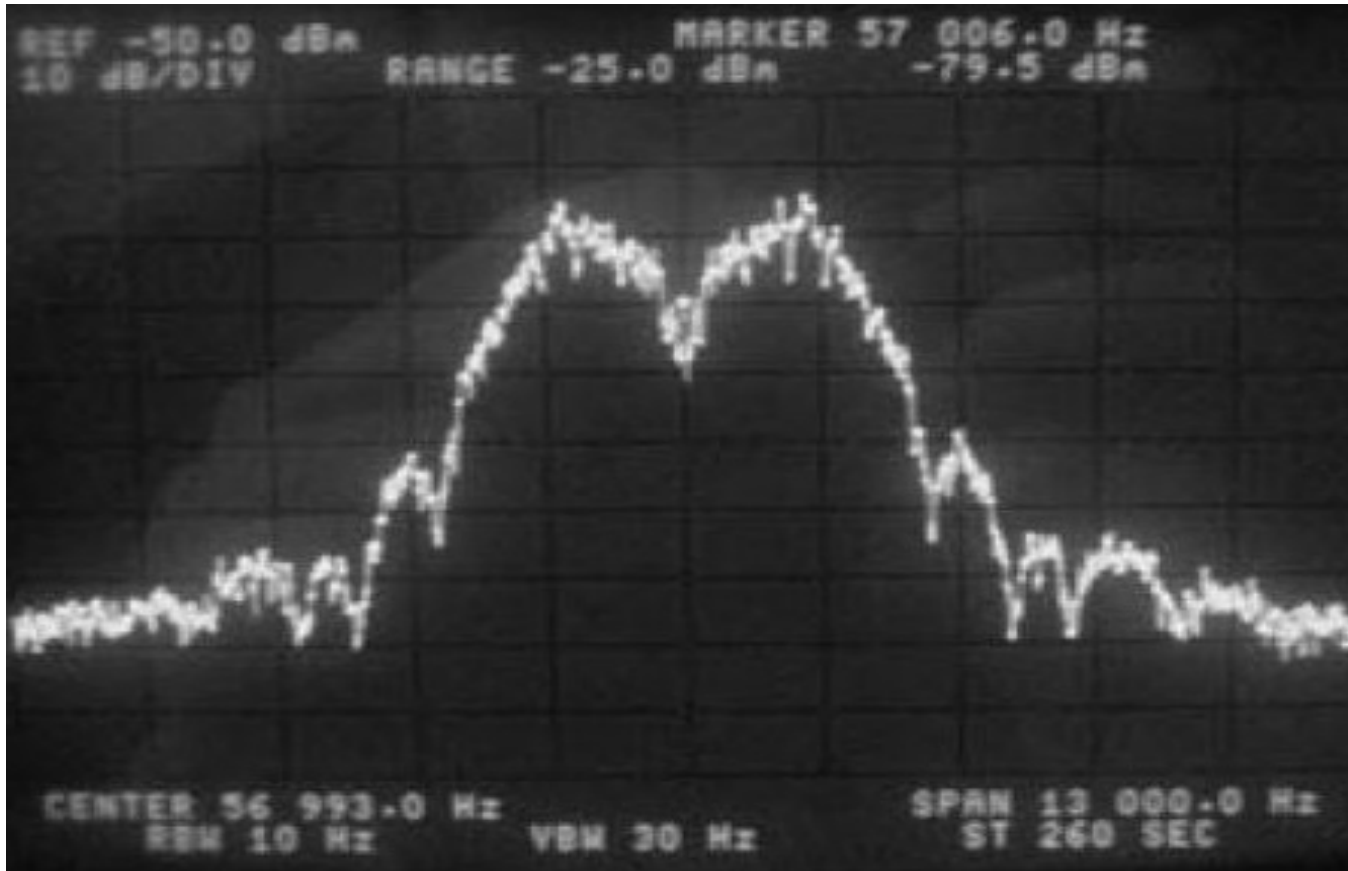


Figure shows the RDS signal in time domain



RDS Encoder signal





RDS Encoder Signal Spectrum

Conclusion



The goal was to make simple RDS Encoder which transmits the Program Service Identification which is Campus FM. That is done using a RDS Encoder which can be used to connect to a PC and a transmitter for collecting data and for generating bi-phase signal. RDS encoder was tested on air with FM transmitter and it worked within expectations.

Future work on RDS encoder is to implement radio text (RT), enhanced other network information (EON) and clock time (CT) and M/S Music Speech.