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DIRECTIONAL INFORMATION VOR SYSTEM IN THE ACOUSTIC MEDIUM

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Summar The article describes design of didactic aid. Main reason is visualization and theoretical explanation of making course information of system DVOR. First par is focused to theoretical background of ground station of system DVOR – which signal is used and how they are generated. Second part is focused on aircraft part of system DVOR – receiver. Theoretical background provides main starting point for design an electronic receiver of DVOR simulator. DVOR transmitter is built as another master thesis. This simulator uses for his function acoustic waves. In real. Frequency used in DVOR is too high for hearing, so it was a good choice use acoustic waves. Acoustic waves are affected by Doppler effect same as radio frequencies, so we can use them for simulation of DVOR system. DVOR transmitter transmits reference signal with amplitude modulation and frequency modulated variable signal. From this signals we can get course information as real DVOR system. This receiver is supplement to DVOR transmitter and together makes didactic aid of complete DVOR system.

Keywords: DVOR, Doppler, receiver, transmitter, didactic, aid, VOR, information, directional

1. INTRODUCTION

The teaching process of systems VOR and DVOR are realised as presentation which describing theory of this systems. In this situation completely missing real visualisation of function of systems and connection to real systems. Systems VOR and DVOR are quite difficult to understand for student, so this is main reason why this work was realised. These systems works on radio frequency and allows navigate airplane to airport and runway for landing or with VOR/DVOR is aircraft capable to navigate in space and fly to requested direction. This simulator uses acoustic waves. Main reason is closely connection between student and transmitted signals. They can hear it and thy can understand it. In acoustic mediun we can use same principles as are in radio waves. Acoustic waves are affected by Doppler shift same as radio waves. Doppler shift is main principles of DVOR system.

This work illustrate aircraft on-board equipment as DVOR receiver and display unit for pilots. Work is supplement to DVOR transmitter which is designed in another master thesis.

In first time was necessary collect some theoretical articles about VOR and DVOR system. Those articles provide theoretical background for designing of simulator. Systems VOR and DVOR uses a lot of different signals and two basic modulations. Ground stations transmits reference signal, in VOR is frequency modulated, in DVOR amplitude modulated. Second signal is variable. Final modulation of variable signal is created at point of receiving. DVOR simulator uses the same principles of modulation.

The main theoretical articles which was used in this works was notes from lectures about VOR/DVOR at subjects Navigations systems I and Navigations systems II. For design it was datasheets from integrated circuits and books focused on operation amplifiers and work with analogue signals.

Output of this work is device which is capable receiving transmitted signals from DVOR simulator. After received those signals device is able to demodulate signals, compare phases of reference and variable signals and displays azimuth between point of receiving and point of transmission..

2. BASIC PRINCIPLES OF VOR SYSTEM

Shortcuts VOR comes from English Very High Frequency Omnidirectional Radio Range. It is one of navigations systems which allows to pilots navigate flight and find direction of aircraft. Pilots can find direction if fly to VOR/DVOR beacon or from beacon.

System VOR works with radio frequency in VKV spectrum VKV from 108 to 118 MHz. Main disadvantage of VKV is radio range. Range is limited by radio visibility between transmitter and receiver. This system is one of navigations systems of close range navigation. Final range is dependent on location of ground stations – transmitters. Range is also affected by terrain obstacles. Effective range is shown on Figure 1.

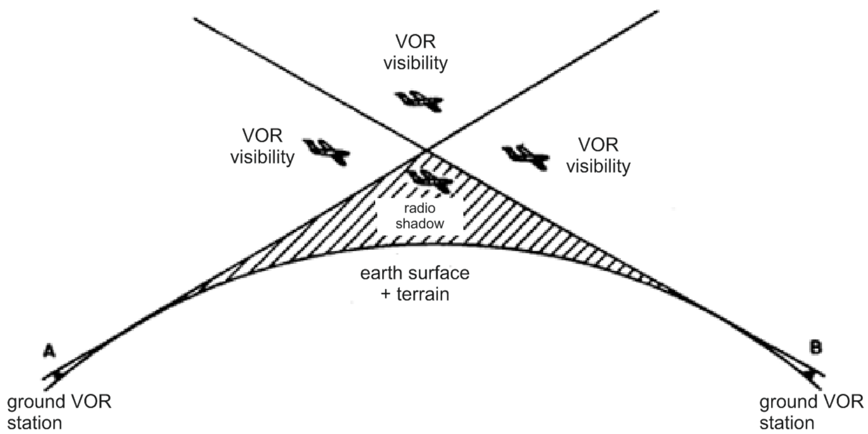

Figure 1 Effective range between ground station and aircraft

Navigation system VOR allows:

- Direct fly to or from ground stations
- Fly on requested route
- Specify of position of aircraft
- Receiving of identifications marks of VOR ground stations

VOR ground stations works in first aircraft radio range. Lower frequency is 108,00MHz, upper frequency is 117,95MHz. Channels gaps are 50kHz. VOR uses 160 active channel from maximum 200. Rest of channels (40 channels) are reserved for LOCALIZER (LOC). LOC with GLIDESLOPE GS are part of landing system ILS.

Basic VOR parameters :

- Frequency range 108,00 ÷ 117,95 MHz
- Frequency channel gap 50 kHz
- Active channels 160
- Nominal accuracy 2°
- Frequency of reference signal 30 Hz
- Frequency of variable signal 30 Hz
- Frequency of second modulation signal 9960 Hz
- Frequency of identification signal 1020 Hz

2.1. Ground station of VOR

VOR beacon transmit two radio VKV signals from one device. One of them is signal with reference phases transmitted by omnidirectional antenna. Phase of this signal is not depend on position of receiver. This signal is amplitude modulate by signal with frequency 9960Hz in next step is this signal modulated by harmonic signal 30Hz with frequency shift 480Hz. This modulation is depend on variable signal transmitted with directional antennas system with cardioid characteristic. Maximum of frequency shit must be transmitted when characteristic of variable antenna system points to magnetic north. Carry signal is also amplitude modulated by1020Hz frequency. Identification signal is transmitted by omnidirectional antenna. This signal which is transmitted by omnidirectional antenna can be describes mathematically as:

$$u_r(t) = \left\{U_0 + \Delta U cos\left[\omega_m t + m_f \sin(\Omega t + \Psi_r) + \varphi_m\right] + \Delta U_i \cos(\omega_i t + \varphi_i)\right\}\cos(\omega_0 t + \varphi_0)$$

Where :

- mf – index of frequency modulation

$$m_f = \frac{\Delta\omega}{\Omega}$$

- $\Delta\omega$ – frequency shift
- Ω – frequency of signal

Basic illustrations of signal transmitted by VOR are shown on Figure 2. First signal is modulation signal 30Hz. Second part of picture is FM modulated signal by 30Hz with frequency shift 480Hz. Last part is final result of modulations. Amplitude and frequency modulated signal which carry information about reference phases and identification markers. This signal continues to power amplifier and is ready to transmit by omnidirectional antenna.

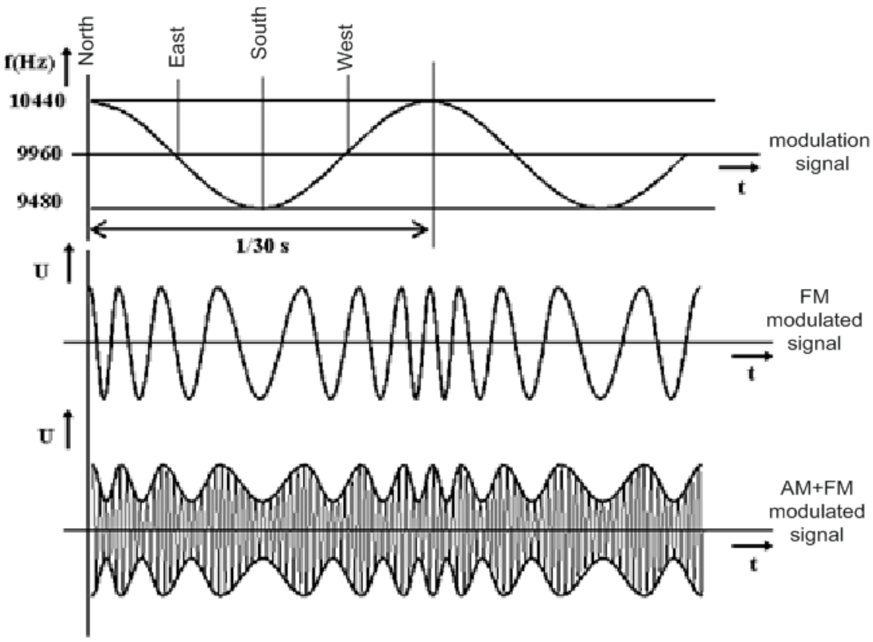

Figure 2 basic illustration of VOR signal

2.2. Aircraft receiver of VOR system

Onboard aircraft receivers of system VOR are in most cases common heterodyne types with automatic gain control function. Signals which are received by antenna are processed in receiver. Superheterodyne receiver is based on constant intermediate frequency which carries informations. This intermediate frequency is constant no matter what is frequency of inputs but it must be in specified ranges. This constant intermediate frequency is result of difference between received signal and variable frequency main oscillator in receiver unit. This oscillator change frequency depend on input received signal. Result of difference this two signals is constant signal which conserved informations in original signal.

Aircraft VOR receivers are fully compatible with DVOR ground stations. After receiving of signals, these signals are transfer to intermediate frequency, filtered and demodulated.

Demodulated signal consist from this parts:

- Identification marks of transmitter beacon
- Audio voice signal
- Signal with reference phases
- Signal with variable phases

Audio voice and identification marks are gets by amplitude demodulations and filtrations on 1020Hz. Another way is use low frequency amplifier with limited input spectrum of frequencies. Signal is connected to the pilots headphones.

Filter tuned on 30Hz is used to divide signal with variable phases which depend on point of direction to transmitter. On output of filters tuned on 9960Hz is frequency modulated signal with reference phases. After frequency demodulation system gets reference phases.

If transmitted signal will be modulated by identification signal, final equation for descriptions of received signal by antenna will be in form :

$$u(t) = \{U_0[1 + mocs(\omega_m t + m_f \sin(\Omega t)) + m_i cos\omega_i t] + U_1 \cos(\Omega t + \Delta\Psi \ )\} \cos(\omega_0 t)$$

By demodulations of final signal from radio beacon VOR we gets two signals :

- signal with reference phase 30Hz
- signal with variable phase 30Hz

Next figure describes signals in time with variable and reference phase and final signal from VOR beacon

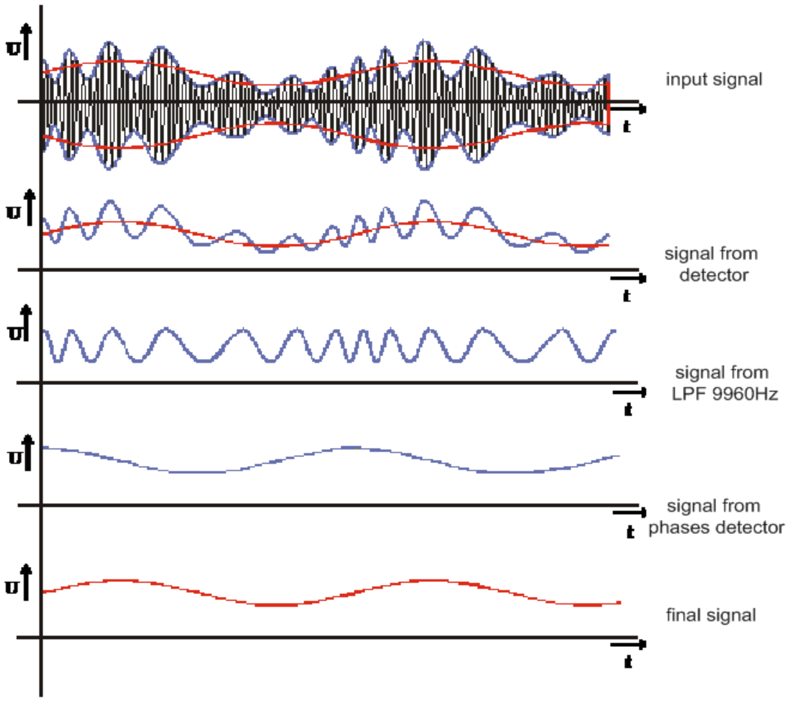

Figure 3 basic illustration of VOR signal

In first graph is model of input signal which is receive by antenna system on aircraft. Signal is amplitude and frequency modulated. After amplification and filtering signal enters to the detector. Output of detector is on second model of figure 3. After low pass filtering we gets frequency modulated signal with reference phase which enter to the phases comparator. Variable phase signal is product of amplitude demodulations of this signal. Both signals enters to phases comparator. Output of phases comparator is information about phases differences and in results, information about course – angle between aircraft and ground station.

3. ELECTRONIC PART OF SIMULATOR

From theoretical background is possible to design an electronic receiver of acoustic simulator. The basic block schematic is shown on figure 4.

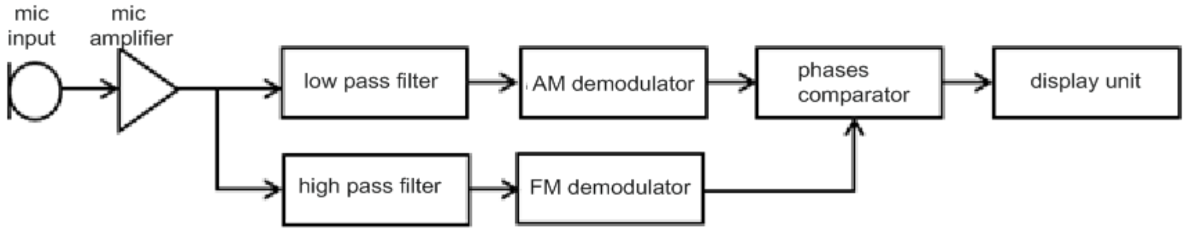

Figure 4 Basic block diagram of receiver

It consist from these blocks :

- microphone – it receive an input signal and transfer acoustic waves to electrical signal
- mic amplifier – amplitude of signal from microphone is too low for filtering and modification so it is necessary amplified it. This block has gain 100 and provides 1V amplitude for next steps. It is used LM386 which is specially designed for microphone amplifiers and AM-FM modulators/demodulators.
- Low pass filter – It provides basic filtering for AM demodulator. It is active filter with 24db/oct equalization. Filter is designed to 500Hz /-3dB frequency. This frequency was tune by experiment with acoustic DVOR transmitter. When was used high frequency, signal was noisy. With lower frequency some information was missing. The DVOR acoustic transmitter provides amplitude modulation in this range.
- High pass filter – provides filtering for FM demodulator. It is also active filter with 24dB/oct equalization. We need all information from signal so filter is tune at 500Hz also. High pass filter separate FM modulated signal from signal from input. AM signal is separate by low pass filter from previous stage. Filters are parallel with common inputs.
- AM demodulator - for demodulation of AM reference signal is used common used type of demodulator. After demodulation it provides reference phases information for course information.
- FM demodulator – Variable signal from transmitter is FM modulated. Input to this modulator is FM modulated signal which provides variable phases information. This phase is dependent on time of receiving signal – relative to position transmitter / receiver.
- Phase comparator – Inputs are results of demodulations. One signal is reference signal from AM demodulator. Second input is variable signal. Output of phase comparator is DC voltage which depend of comparison this two inputs phases. Phases comparator consists from two operation amplifiers on inputs. They works as limiter/clipper on inputs. Amplitude of signal on this input must be higher than 35mV.Limiters limit signal amplitude if is higher as 0,7V. Second part of comparator is CMOS schmitt trigger. This trigger can react on rising or falling edge of input signals. This part work as zero crossing detection pulse generator. Last part of phase comparator is counter with DC output. Counter counts impulses from Schmitt trigger and result is DC voltage.
- Display unit – unit consist from a few parts. Main part is microcontroller. It measure DC voltage from phases comparator and compute actual course information. Measured and re-computed data are displayed on display unit. In this case 2x16 character LCD. It can be replaced by analogue meter scaled to course angles.

4. CONCLUSION

The main theme of this article was design and realisation of receiver unit for DVOR acoustic simulator. The main part – DVOR simulator is only transmitter. It transmits AM reference signal and FM variable signal. In this work was introduced receiver for DVOR transmitter. It consist from two main filters, which are tuned on 500Hz. This frequency was find by experiment. Next stage is amplitude and frequency demodulator. On the outputs we gets signals with variable and reference phases. Variable phase is product of frequency demodulator and reference phase is product of amplitude demodulator. This two signals enters to the phases comparator. Output from phases comparator enters to display and measure unit. This allows display and measure this signal with good precision and user friendly representations of results. Theoretical accuracy is 0,5°. Real accuracy was not measure.
It is supplement and together makes didactic aid capable simulate system DVOR as ground station and aircraft equipment.

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