FSK AND GMSK DETECTORS

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ABSTRACT

The paper deals with a comparison of two realizations of quadrature demodulators for the FSK and GMSK detection. The advantage of these modulations utilization in space communication is mentioned. The basic conditions are discussed. Two integrated circuits were chosen for final realization. The first one uses older TBA120U which was essentially designed for analogue demodulation. In the second case, the modern, small packaged TK14588V is utilized. The main comparison is accomplished on a basis of the linearity of the transfer characteristic which is denoted as an S-curve.

1. INTRODUCTION

Nowadays, the classic analogue frequency modulation FM is being used mostly for radio broadcasting. Through the time within the digital communication development, digital versions of FM have been derived – frequency shift keying FSK and Gaussian-filtrated minimum frequency shift keying GMSK [1], [2]. These modulations reach good energetic and spectral efficiencies in very poor conditions in a communication channel, such as long communication distances, a high object velocity connected with the Doppler frequency shift, a small signal to noise ratio, delays and data deformations. These conditions are typical for space communications, which the circuit was designed for as a result of a diploma thesis [1].

The general conception of the superheterodyne receiver with one intermediate frequency stage is shown in Fig. 1.

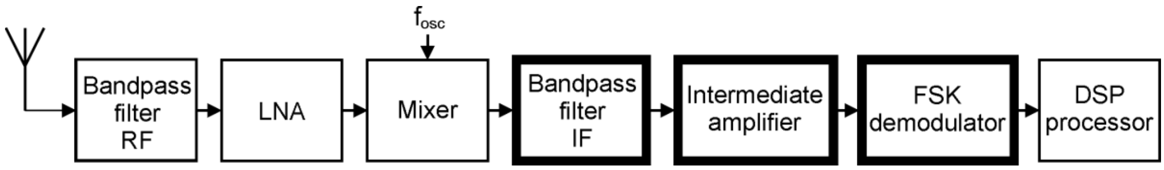

Fig. 1 Superhetorydyne receiver block scheme

The received signal goes through a high frequency bandpass filter to a low noise amplifier LNA. The amplification causes the increase of the SNR. A mixer down-converts the signal to the intermediate pass band. After a bandpass filtration and an amplitude limitation in an intermediate amplifier the signal is demodulated to the base band. Following processing is made by DSP. The highlighted blocks are objects of the design.

2. FSK AND GMSK DETECTION

There are several ways how to demodulate FM or FSK signals, respectively. Very simple demodulators are the slope detector and the Foster-Seeley detector. They are characterized with a less accuracy and a less stability. On the other hand very precious detection can be achieved with a phase lock loop PLL. But this way is quite complicated. For the simplicity and satisfactory qualitative parameters the quadrature detector was chosen for this project solution [1].

2.1. FSK AND GMSK DIFFERENCES

FSK is a two-state modulation technique [2], [3]. Each carrier state exhibits one bit of the modulation signal. The phase continuity between switched states is not guaranteed. This leads to a parasitic amplitude modulation and a spurious spectre extension can be observed.

GMSK is also the two-state modulation technique derived from MSK [2], [3]. The phase continuity between each state is assured, when the carrier frequency is equal to the integer multiple of the signal bit rate. In addition, the input square modulation signal is filtrated with the Gaussian filter.

On the receiver side before the IF amplifier and the detector the IF filter has to be placed. The filter for GMSK is derived on a basis of the RC filter that is defined by the roll-off factor β [2]. This factor establishes the increase of the filter bandwidth in a comparison with the Gaussian squared filter bandwidth and its value can vary between 0 and 1. The modulation signal for FSK is not filtrated at all, so its spectrum is very broad, ideally infinitely broad. For calculations the factor β value was chosen to 1 to cover the both modulations FSK and GSMK, respectively. (1) shows the relation for the IF filter bandwidth calculation.

$$B = \frac{1+\beta}{T_b} \tag{1}$$

B means the IF filter bandwidth and T_b is the data bit period [1].

Practically, an appropriate ceramic filter was chosen as an IF filter.

2.2. QUADRATURE DETECTOR PRINCIPLE

A simplified diagram of a quadrature detector is shown in Fig. 2a). It is composed of two main parts. The first one is an analogue multiplier realized within a Gilbert cell. It is mostly integrated inside an integrated circuit and thus there is nothing significant to design. The second part is being denoted as a phase shift network. It assures a phase shift between signals on two multiplier inputs [1], [4].

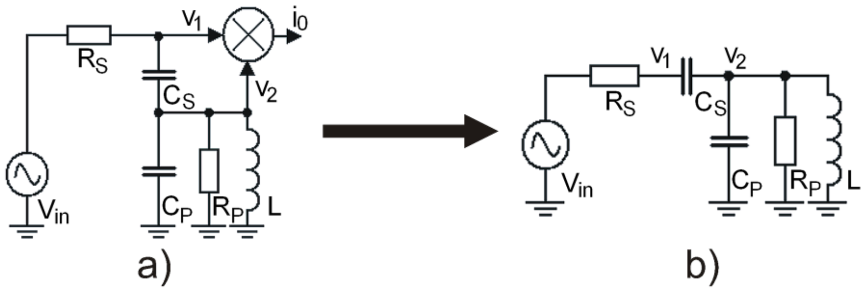

Fig. 2 a) principle circuit of the quadrature detector, b) quadrature detector model

Fig. 2b) shows the small signal model of the phase shift network. It consists of a serial capacitance C_S and a parallel resonance tank $R_P L C_P$. All these components are mostly outside an integrated circuit package and they have to be calculated correctly [1], [4].

The multiplier output current is dependent on a difference between the input voltage v_1 and v_2 phases. After mathematical arrangements the relation for the multiplier output current i_0 has been derived, see (2).

$$\frac{i_0}{2I_0} = const \cdot \frac{a}{1+a^2} \tag{2}$$

$i_0/2I_0$ expresses a normalized output current and a is a normalized frequency deviation. The term *const* refers to a current detector configuration.

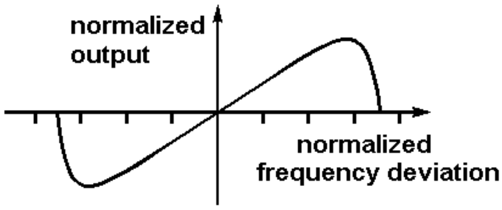

Fig. 3 S-curve of the quadrature detector

Fig. 3 shows the transfer characteristic of the quadrature detector, usually denoted as an S-curve. Frequency variations of the input signal are creating output current changes which can be converted to voltage changes. They express a demodulated signal leading to subsequent circuits. The most important part of the S–curve is the linear section around the centre of a diagram, see Fig. 3. The more linear this section is the less nonlinear distortion is included in the demodulated output signal. Components of the phase shift network are computed for these conditions [1], [4].

3. INTEGRATED CIRCUITS FOR FSK AND GMSK DETECTION

Very important thing for the final realization was choosing the appropriate integrated circuit which includes both the IF amplifier and the quadrature detector. Nowadays worldwide market provides quite a rich offer of various integrated circuits which accomplish required parameters. But most of them are not available in national market. Finally, two integrated circuits were chosen and gained from suppliers. The following paragraphs summarise the ICs structure and utilization in the solved problem for given bit rate 76,8 kbps and the intermediate frequency 10,7 MHz.

3.1. TBA120U

TBA120U, the Philips company product, is the older one of the chosen ICs. It is the most available circuit in the national market and its properties have been checked up within the long term usage. This circuit was originally built for the sound demodulation in TV tuners. In turn, TBA120U has been used in other amateur constructions including digital ones. The internal structure of TBA120U is depicted in Fig. 4a). The circuit contains main blocks such as the IF amplifier and the analogue multiplier (both in differential versions) and then the uncontrolled output amplifier. These blocks are utilized in the realization. The internal reference and the controlled output amplifier are not used [1], [5].

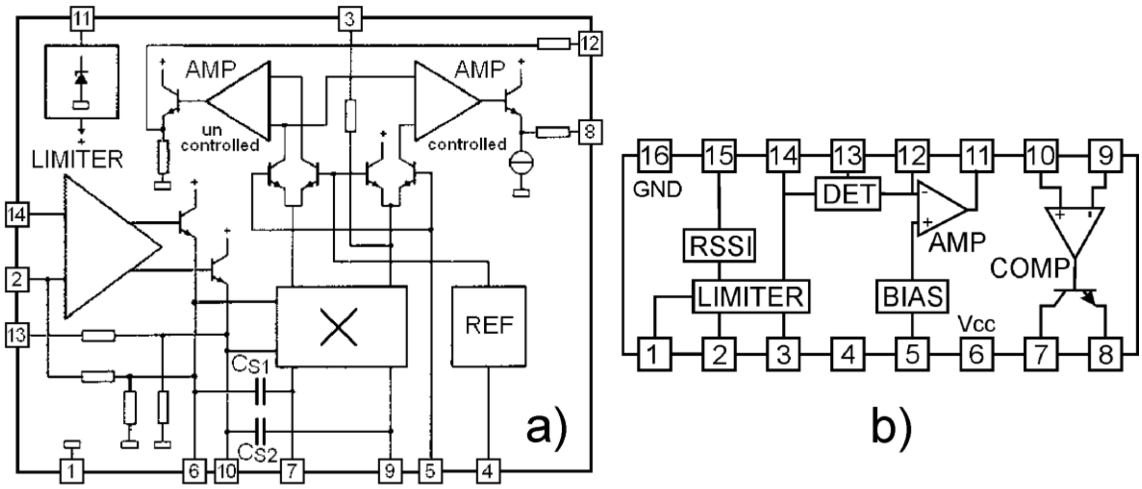

Fig. 4 Inner structure a) TBA120U, b) TK14588V

The biggest disadvantage of TBA120U is the integration of the phase shift network serial capacitors C_{S1} and C_{S2} on the chip. The capacitors have big values (50 pF) which are not convenient for a lower bit rate design. The calculations give a very small inductor inductance which can not be technically realized with a casual technology.

The measured S-curve of the final realization for the bit rate 76,8 kbps is shown in Fig. 5. A marked section of frequency changes is included in the linear area of the S-curve [1].

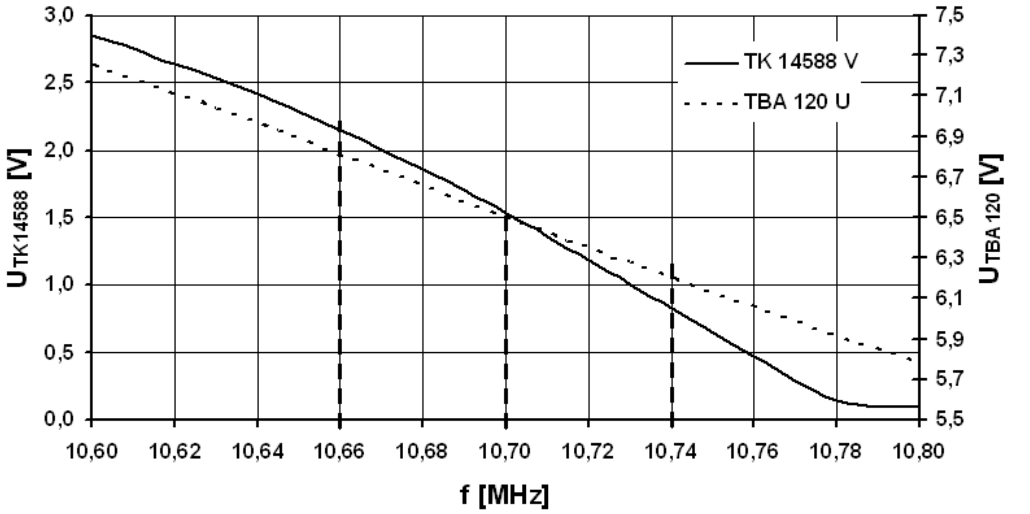

Fig. 5 Measured S-curves for bit rate 76,8 kbps

3.2. TK14588V

Integrated circuit TK14588V is a modern circuit, primarily made for receivers within a digital signal processing made by TOKO company [6]. Fig. 4b) shows its internal structure. The package contains basic parts as an intermediate amplifier (limiter), a detector (det), and an output signal amplifier (amp). Limited input signal is fed into two detector inputs, to the firs directly, to the second through the outer phase shift network. The detector output is current and is transferred to voltage within the output amplifier. In addition, an included comparator (comp) provides the detected signal shaping into a square wave at the output. All phase shift network components are connected from the outside of the package. This is a very big advantage that allows designing the circuit for a various conditions.

The measured S-curve of this realization for the bit rate 76,8 kbps is also shown in Fig. 5. Same marks, as for TBA120U, point at the linear area for the given bit rate [1]. The TBA120U S-curve is flatter and the linear area is longer. It is mainly caused by inner parasitic capacities and resistances, which lead to the quality factor lowering.

4. CONCLUSION

Both equipments with TBA120U and TK14588V were constructed, tuned and their parameters were measured. The most significant parameter of the demodulator is the transfer function linearity in the working frequency band.

Measured S-curves for both cases are sufficient as shown in Fig. 5. But in the matter of constructional side, the better solution is achieved with TK14588V. Firstly, this circuit is modern which secures longer term utilization of the design. Further, it offers very small package with minimum outer components. In addition, it provides more possibilities to adjust the circuit according to the user requirements. The shaping network in the output is also a very useful part. The IC needs a small supply voltage with small power consumption.

Due to the advantages of TK14588V, three sections were constructed. Each section processes signal with the single bit rate. Given bit rates are 38,4 kbps, 76,8 kbps and 153,6 kbps. The designed equipment is going to be used in a digital satellite receiver.

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