IF OQPSK MODULATOR FOR IMTEL RRU 13A RADIO-RELAY LINK

Dorđe Simić, Miroslav Perić, Predrag Manojlović
IMTEL Institute, bul. Mihaila Pupina 165b, Novi Beograd, e-mail simke@zormi.com

I. INTRODUCTION

New generation of the Institute IMTEL digital radio relay links, working in 13 and 23 GHz frequency bands, employs OQPSK modulation scheme in order to keep the track with current and forthcoming international standards [1], [2], regarding channel spacing, bandwidth and spurious emissions proposed by ITU and ETSI. This paper deals with realization of the modulator employed in radio-relay link IMTEL RRU 13A. More attention is paid to analysis of the modulator performance and overall system requirements.

RRU 13A works in 13 GHz frequency band where channel spacing of 7 MHz is prescribed by the international standard [1] for use with 2/8 Mb/s digital microwave radios. Without any changes this circuit can be used for much higher data rates and even high-level modulation schemes. This feature originates from wideband modulator architecture. Since the RRU 13A is constructed with one up-conversion [4], 1274 MHz has been chosen as convenient value for transmitting intermediate frequency, well agreed with receiving intermediate frequency chosen by the manufacturer and Tx/Rx spacing [1], [4].

This paper deals with practical realization of the IF OQPSK modulator and is composed as follows. In Section 2. the general OQPSK modulator architecture [3] has been analyzed with emphasize on nonlinear effects in modulator circuit.

Special attention is paid to carrier and sideband suppression. Section 3. deals with the realization of the particular circuit and describes in greater details chosen implementation.

Measured results have been presented in Section 4 along with thorough analysis of eye diagram pattern regarding nonlinearities in output power amplifier. Our conclusion has been given in Section 5.

II. THE QUADRATURE MODULATOR

Because the overall performance of the system can be affected by the modulator, its performance is important. Therefore, the need to optimize the carrier suppression and the sideband suppression of a quadrature modulator often arises. The primary reason is that there are imbalances in the mixers and phase error introduced by the phase-shifting network. These imperfections are caused by slight differences in devices. There are also imbalances and offsets between the in-phase and quadrature signal paths as a result of process variations. These errors are not present in an ideal device, however they cannot be eliminated in practice.

The block diagram of a typical quadrature modulator is shown in Figure 1.

![Fig. 1. Basic quadrature modulator architecture](image)

If we assume that in-phase and quadrature signals are given like follows:

\[ I(t) = A \cdot \cos(wt + \phi) + B \]  \hspace{1cm} (1)

\[ Q(t) = \sin(wt) \]  \hspace{1cm} (2)

Where \( A \) denotes relative amplitude ratio of the signals \( \phi \) is phase, and \( B \) is DC offset between signals. We assume that all imperfections in the modulator circuit can be modeled with these values. Therefore, modulated RF output signal is given by:

\[ s(t) = A \cdot \cos(\omega t + \phi) \cdot \cos(\omega_0 t) + B \cdot \cos(\omega_0 t) + \sin(\omega_0 t) \cdot \sin(\omega t) \]  \hspace{1cm} (3)

where \( \omega_0 \) denotes carrier frequency. From this equation is easily seen that carrier suppression depends on DC offset, and as can be seen, the carrier can only be present at the output if there is a DC offset between the input signals. Later
we will show how improvement is achieved by adjusting DC offset. After some elementary math manipulation from equation 2 we come up with expression for the sideband suppression [5].

$$\text{Supp} \, \text{dBc} = 10 \log \left[ \frac{A^2 - 2A \cdot \cos \phi + 1}{A^2 + 2A \cdot \cos \phi + 1} \right]$$

(4)

Figure 3. depicts family of sideband suppression curves versus amplitude and phase errors based on previous equation.

Since sideband suppression depends on both amplitude and phase balance it can be improved by adjusting either value. Of course, the amplitude imbalance is much easier to diminish, and therefore the phase imbalance remains as major cause of poor sideband suppression.

III. THE PRACTICAL REALIZATION

The modulator for RRU13A enables, besides basic, modulating function also and additional filtering and output power control functions. Output power control for RRU13A is possible at IF because of the fact that output amplifier must operate in linear regime in order to keep distortion in modulated signal at acceptable level. Figure 2. shows block scheme of the modulator device and on Figure 4, the photograph of realized device is shown.

The local oscillator signal at 1274 MHz is synthesized using PLL and supplied as local oscillator to the quadrature modulator. Modulating signal is supplied divided in in-phase and quadrature signals, shaped by base band filters with time offset equal to half of a symbol period. Output power control is attained through variable attenuator with attenuation of 0-22 dB. Suppression of out-of-band emissions is achieved by band-pass filter, and desired maximum output power level of +3dBm is gained with output amplifier.

Figure 2. IMTEL RUU13A modulator block scheme

Figure 3. Sideband suppression vs. amplitude and phase error

Figure 4. Realization of the RRU13A modulator

IV MEASURED RESULTS

Phase error is inherently dependant from the quadrature modulator architecture and very little can be done to compensate this error by any external circuit. Contrary to this, amplitude error, as well as DC offset can be easily compensated in order to achieve maximum carrier and sideband suppression. We have used both methods to improve performance of our device. As test signal we use 2.240 MHz square wave. On Figure 4, the spectra of signal modulated with 2.240 MHz signal is shown where both compensation methods have been used. Carrier suppression
of 51 dB, and sideband suppression of 46 dB are achieved. This is 15-20 dB more than is accomplished with uncompensated modulator.

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V CONCLUSION

This paper deals with practical realization of quadrature modulator employed in IMTEL RRU13A digital microwave radio. Analysis of architecture and performance are presented, as well as methods used for performance optimization. Presented architecture is suitable for use in higher-rate radio-relay links and even multi level modulation schemes.

REFERENCES:

[2] ETS 300 639: "Transmission and multiplexing; Sub-STM1 Digital Radio Relay Systems operating in the 13 GHz, 15 GHz and 18 GHz frequency bands with about 28 MHz co-polar and 14 MHz cross-polar channel spacing", ETSI October 1996

Abstract – New ETSI and ITU regulations prescribe more stringent rules for spectrum allocation in microwave frequency bands used for digital radio relay equipment. This implies usage of frequency-efficient modulation methods for data transmission. This paper deals with realization of intermediate frequency OQPSK modulator employed in the RRU 13A digital microwave radio-relay link manufactured by Institute IMTEL.

OQPSK MODULATOR NA MEĐU-UEESTANOSTI ZA RADIO-RELEJNI UREĐAJ IMTEL RRU 13A
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Fig 7a. Output spectra at 13 GHz; $P_{out} = 23.5$ dBm, Attenuation = 0 dB

Fig 7b. Eye patterns of the demodulated signal at IF and BB, Attenuation = 0 dB

Fig 8a. Output spectra at 13 GHz; $P_{out} = 23.2$ dBm, Attenuation = 4 dB

Fig 7b. Eye patterns of the demodulated signal at IF and BB, Attenuation = 4 dB

Fig 7a. Output spectra at 13 GHz; $P_{out} = 22$ dBm, Attenuation = 6 dB

Fig 7b. Eye patterns of the demodulated signal at IF and BB, Attenuation = 6 dB

Fig 7a. Output spectra at 13 GHz; $P_{out} = 15.8$ dBm, Attenuation = 10 dB

Fig 7b. Eye patterns of the demodulated signal at IF and BB, Attenuation = 10 dB