Measuring bit error rate of transmitter ICs with EMI Test Receiver ESMI

A major quality criterion in data transmission with state-of-the-art communications equipment is low bit error rate (BER). When the whole communications system – consisting essentially of data source, possibly a coder, modulator plus transmitter output stage, receiver with demodulator (and decoder) as well as data regeneration and evaluation facilities – is examined with a view to BER, attention normally focuses on the demodulator. Nevertheless, manufacturers of digital transmission equipment must also be able to characterize their products by specifying the achievable BER.

Since the introduction of ISM (industrial, scientific, medical) bands, a variety of applications involving wireless data transmission can be implemented worldwide without a license in these frequency bands, provided the prescribed useful and interfering signal power and bandwidths are maintained [1]. In Germany, for instance, the 433 MHz band (433.050 to 434.790 MHz) can be used for remotely controlled alarms, garage door controls, meter reading or keyless entry. For such applications a number of major semiconductor manufacturers offer integrated circuits that are mainly designed for ASK (amplitude shift keying) and FSK (frequency shift keying).

**Thesys Microelectronics** of Erfurt, Germany, has been on the national and international markets since 1994 with devices for RF applications. Recent developments include two ICs integrating all ASK or FSK functions on a single silicon chip: TH7101 for ASK and TH7106 for FSK. The two ICs operate in the frequency range 280 to 480 MHz and use PLL synthesis for frequency generation (FIG 1). The external circuit to the reference signal generator consists of no more than a crystal and two capacitors. The loop filter components, e.g., two capacitors and a resistor, are also externally connected. This permits the PLL to be tuned for a specific application by adjusting filter components. The VCO and the power-adjustable output stage are completely integrated and feature low phase noise of approx. –76 dBc/Hz (at 10 kHz offset), low harmonic distortion (better than –30 dBc) and output power of approx. 1 dBm (into 50 Ω).

In the TH7106 the FSK is generated by adjusting the integrated pulling capacitors of the crystal oscillator to the rate of the data signal. With the ASK model TH7101 modulation is performed by multiplier keying.

**EMI Test Receiver ESMI** from Rohde & Schwarz [2] is ideal for measuring transmitter ICs (FIG 2). Besides its excellent characteristics as a spectrum analyzer (20 Hz to 26.5 GHz), scalar network analyzer (20 Hz to 5 GHz), EMC test receiver and noise figure meter (with noise source and Software FS-K3 [3]) in receiver mode, ESMI is able to demodulate AM and FM signals. For this purpose it comprises an AM IF amplifier with ALC (> 60 dB), an FM IF limiting amplifier plus AM and FM demodulators. After selection of the type of modulation, frequency deviation/modulation depth, center frequency, resolution and video bandwidths as well as sweep time, the demodulated information content can be displayed on ESMI in the time domain. If the modulation signal is within the audio frequency range, the signal can also be aurally monitored via the built-in loudspeaker. So basi-
cally all measurements required for assessing the quality of ASK and FSK ICs can be performed.

In addition to parameters like output power, spurious emission or phase noise, measurement of BER (bit error rate) is of particular importance for quantitative assessment of the functions of a digital transmitter IC. Although BER is not a common parameter in manufacturers’ data sheets, specifying the minimum BER is a useful criterion for determining the operating range (temperature and supply voltage). The demodulated signal can be displayed on ESMI and coupled out at the video output at the rear of the instrument. This permits qualitative assessment by an oscilloscope or BER measurement by applying the data to a test system. Resolution and video bandwidths of ESMI can either be selected according to the theoretical values specified for the required bandwidth of an ASK- or FSK-modulated signal or adapted to receiver parameters. In the first case an optimum receiver bandwidth of $B_R = 1.4 \cdot f_b$ should be available for ASK and FSK according to [4], where $f_b$ is the bit repetition frequency (in Hz) or the bit rate ($R$ in bit/s), which corresponds to the reciprocal value of bit period $T_b$ ($f_b = 1/T_b$). The ESMI demodulators perform non-coherent detection of ASK and FSK signals. In this case the functional dependence of bit error probability (or BER) $P_e$ on signal/noise ratio is the same for both types of modulation. Due to normalization of $S/N$ to bit energy $E_b$ at a given noise density $N_0$ in the receiver, the following expression is obtained according to [5]:

$$P_e = \frac{1}{2} \exp \left(-\frac{E_b}{2N_0}\right)$$

For a transmitter IC the gap between the actually generated and the theoretically possible modulation signal becomes greater with increasing modulation frequency. The reason is the lowpass behaviour of the modulators and the finite bandwidth of the transmitter output stages of the IC. Consequently, transmission quality decreases with increasing bit rate. BER decreases according to the relationship $P_e = P_e(f_b)$. FIG 3 shows the recursive dependence of the maximum possible data rate on BER for both ICs TH7101 and TH7106.

The quality of digital communications systems is often described by means of eye patterns. Conclusions can be drawn from the shape and size of the pattern on the type of interference occurring in the transmission system. FIG 4 shows eye patterns at $P_e = 10^{-3}$ and $10^{-6}$ displayed on a digital oscilloscope operating in cumulative mode. The two patterns illustrate the effect of superimposed noise, the eye opening being considerably wider in the case of $P_e = 10^{-6}$ of course.

Dr Andreas Laute (Thesys GmbH)

REFERENCES