A PC-Based Bit Error Rate Measurement System

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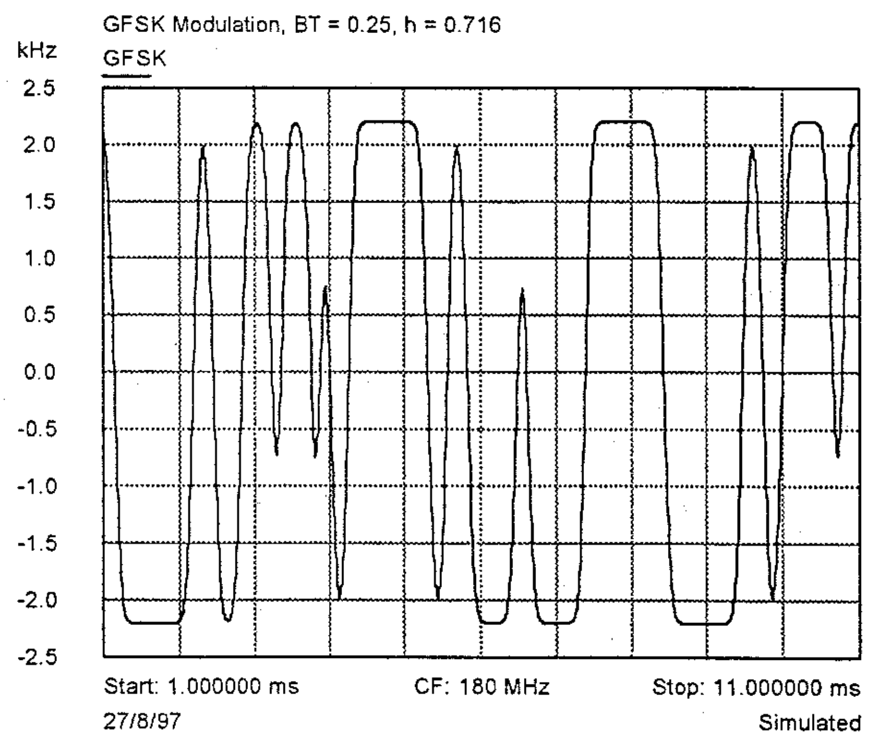
Introduction

When a digital radio project required a Bit Error Rate test system, the author found that the proprietary modulation format precluded the use of conventional BER testers. The solution was to develop a custom system using a PC data acquisition card and software written using Borland Delphi.

Modulation Scheme

The radio is used for two-way data communications on a national digital radio network. It uses a VHF carrier which is frequency modulated using Gaussian Frequency Shift Keying (GFSK). This is an advanced form of FSK where the transitions between frequency states are slowed down by a Gaussian filter to minimise transmission bandwidth. The data rate for this system is 6.144 kbps and the channel spacing is 12.5 kHz. A sample of the modulation waveform is shown below.



Because of the heavy filtering of the modulating bitstream, the carrier only reaches the maximum deviation of 2.2 kHz when a sequence of ones or zeroes are encountered. Alternating ones and zeroes cause the carrier to remain within 0.5 kHz of the mean carrier frequency. The demodulation algorithm makes use of this property.

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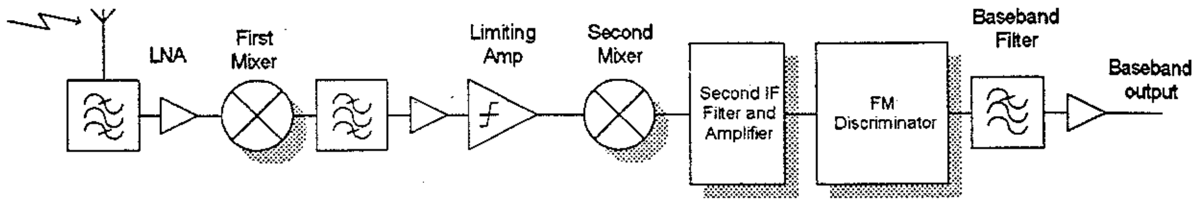
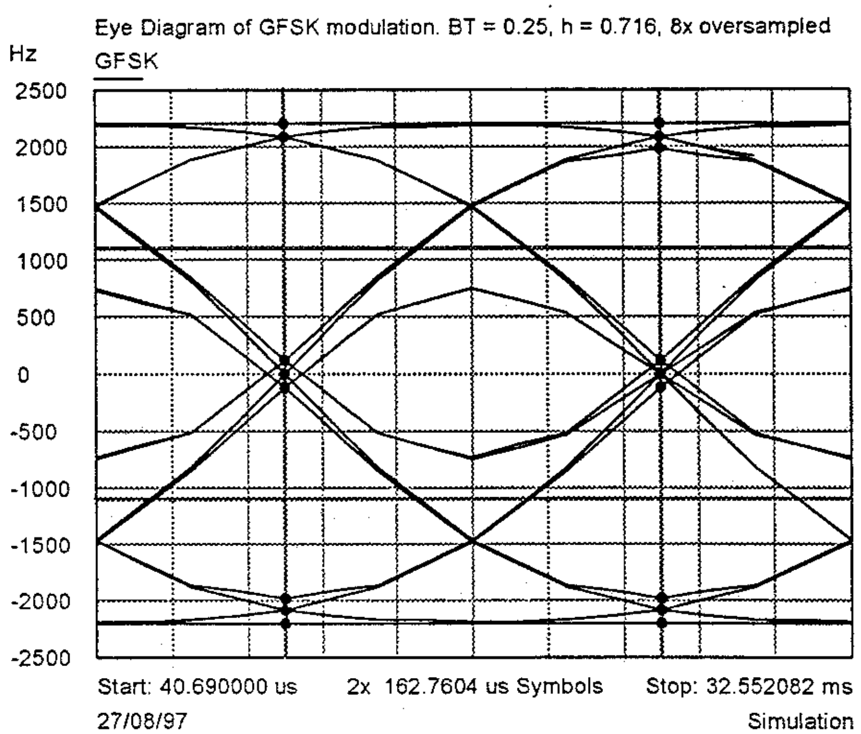
Demodulation Technique

The receiver is a conventional superhet with an FM discriminator at the end of the chain.



The demodulation technique uses an eye diagram representation to determine the modulated bitstream.



First, the demodulation algorithm has to establish the correct phase at which to make level decisions. The data is oversampled by 16 or more times, and then analysed for the highest incidence of zero crossings based on the median of the data. Then using only the samples at this phase, the demodulated waveform is categorised as one of three regions - lower (data 00), middle (data 01 or 10) and upper (data 11). Since the transmitted data is differentially encoded, the demodulation task reduces to middle region (data 1) or the outer regions (data 0).

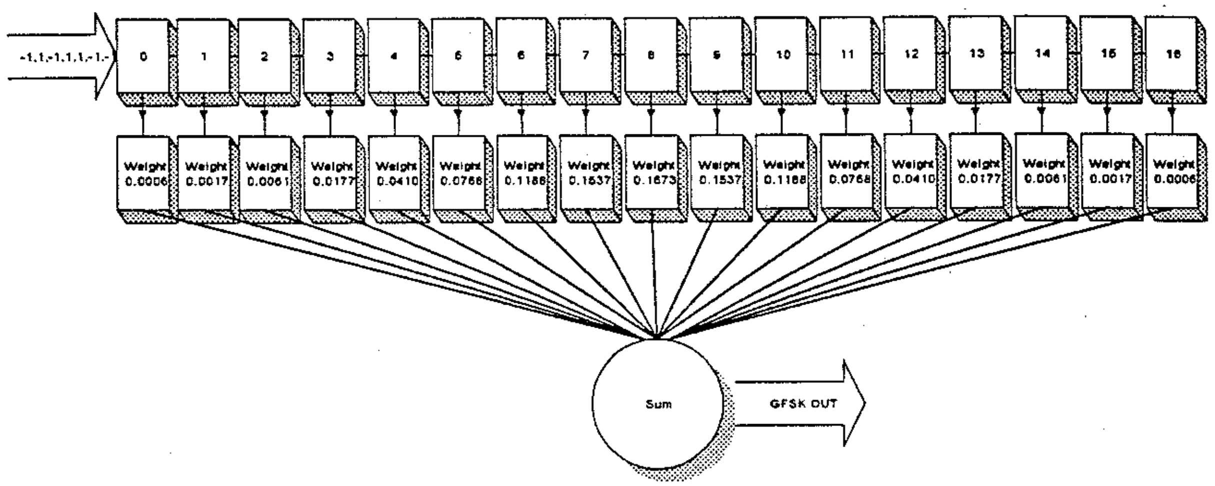
BER Software

In the complete radio, the output from the RF circuitry is decoded by a combination of hardware and embedded software. The BER measurement system is intended to measure the performance of the RF circuitry before the rest of the system has been developed. Therefore it has to perform the demodulation entirely in software.

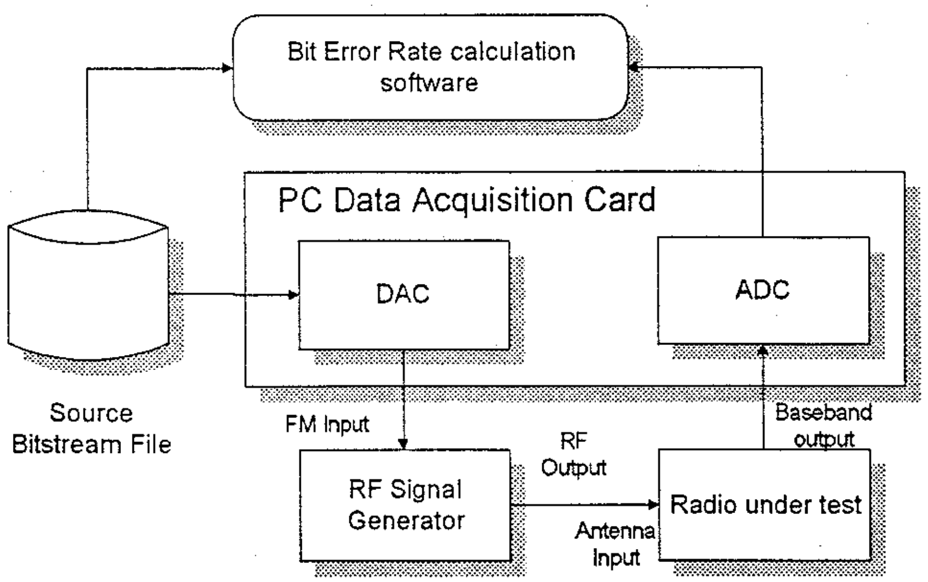
Bit Error Rate is calculated from differences between the received estimate of a bit sequence and the prior knowledge of the actual sequence. For this particular radio system, data is sent in bursts of 768 bits, where 48 bits are used for synchronisation. In order to make the bit sequence comparison, the sync sequence has to be correctly found within the demodulated data stream. There are a specified number of errors allowed in the sync sequence, but if this is exceeded, the whole sequence is deemed to be in error.

Experimental Setup

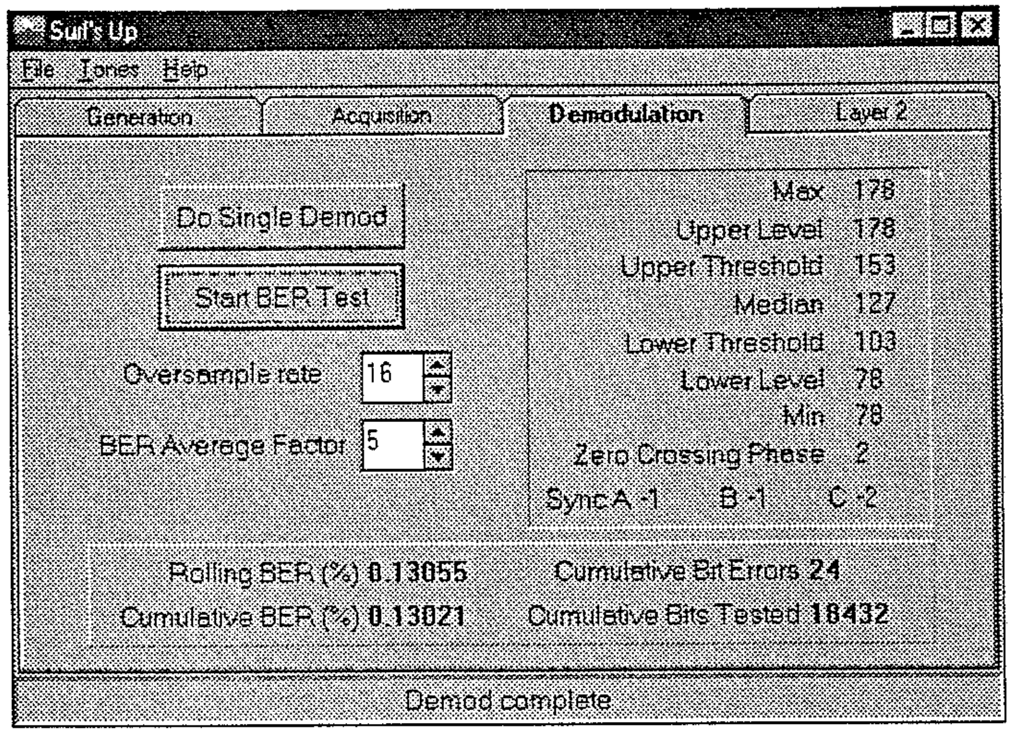
The modulation source data is differentially encoded and then gaussian filtered in software using an FIR filter.



The data is loaded into the data acquisition card's output buffer and played as a continuous loop. The waveform is scaled appropriately such that it produces the correct deviation when applied to a signal generator's FM input. The RF from the signal generator is applied to the receiver's antenna input. The baseband analogue output is digitised by the acquisition part of the data acquisition card. Bursts of data are digitised and then demodulated using the Delphi demodulation software.

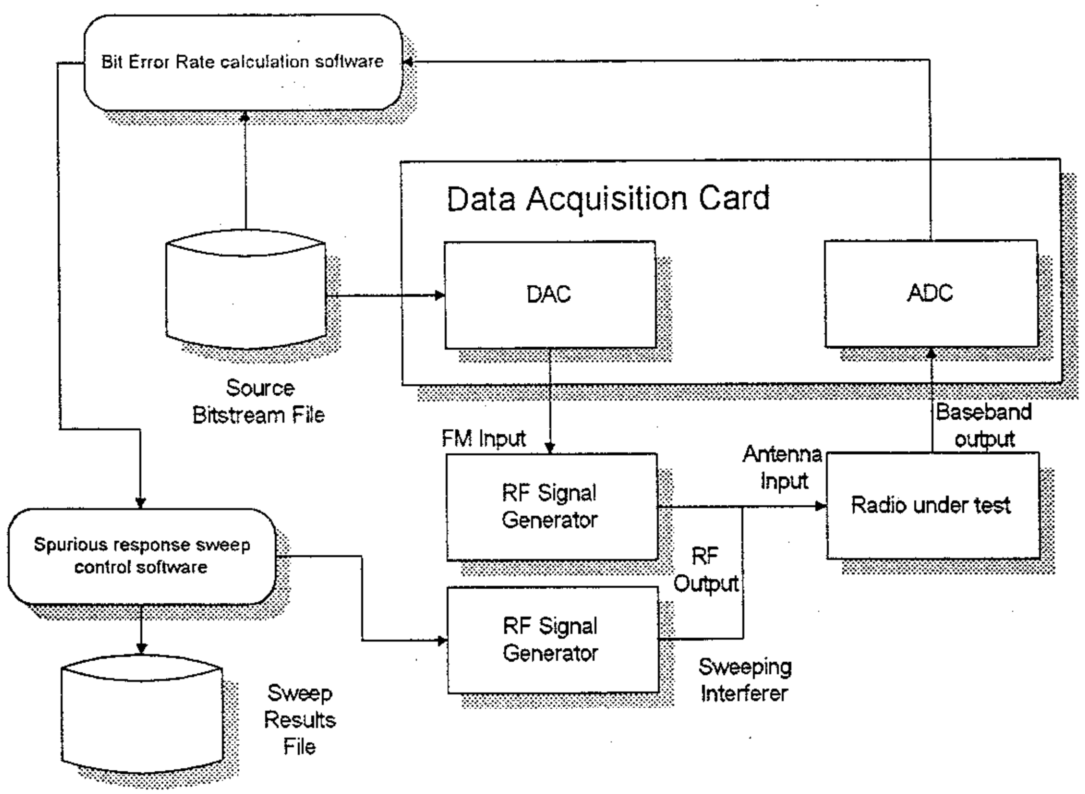


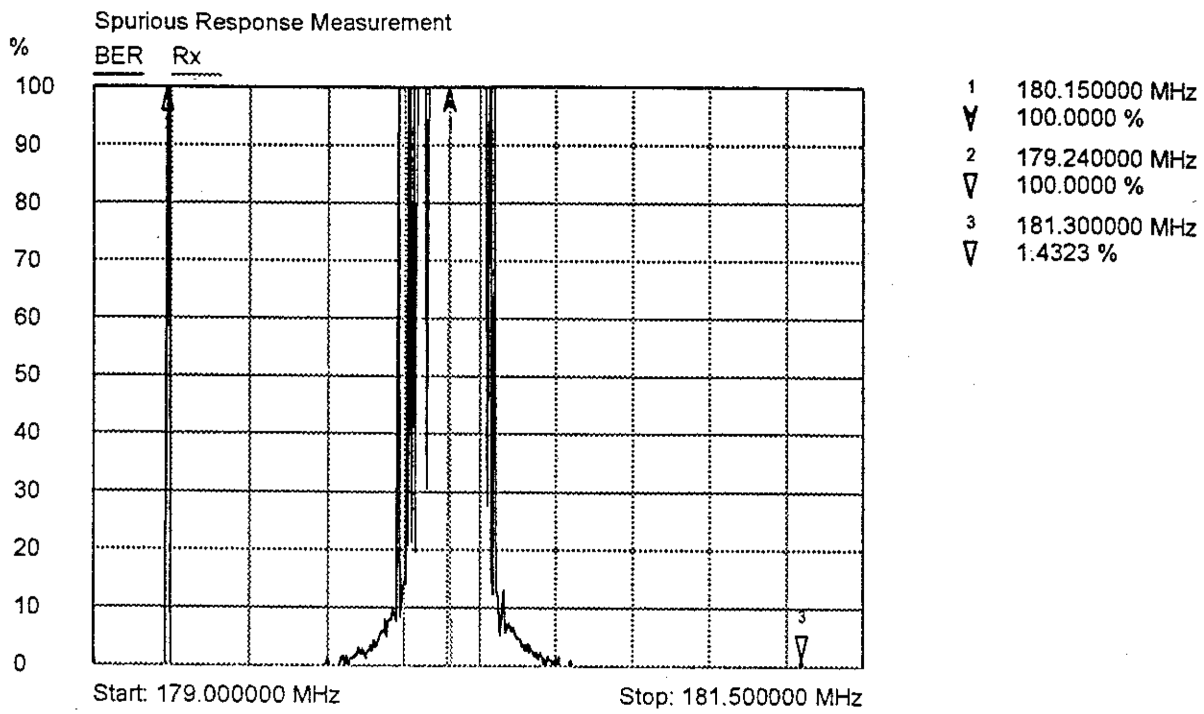
The Bit Error Rate test software is shown below. For small BER measurements, several slots of data can be averaged together to give a cumulative result.



Practical Results

The radio design is tested to ETS 300 113, which calls for several receiver measurements involving Bit Error Rate. Below is a result of a spurious response search, where the receiver is tuned to the test modulation source at -107 dBm, and a second signal generator at 80 dB higher level and with a 1.5 kHz deviation, 400 Hz FM test tone is swept over a wide band looking for an effect on the BER of the wanted reception.





This measurement of an early receiver in the development cycle shows three phenomena. Firstly, spurious signals close to the desired carrier are received to a greater extent than required. This was due to the phase noise profile of the receiver's first local oscillator, which after further investigation was found to be in need of improvement.

Secondly, there is a spurious response at 179.24 MHz. Given that the first LO is at 225.15 MHz to correctly receive the 180.15 MHz signal, this implies that there will be a 45.91 MHz IF signal present along with the desired 45.0 MHz signal. This corresponds to the image response of the second down-conversion, which has a local oscillator at 45.455 MHz. Consequently the fault lies in a leakage path around the first IF filter.

Thirdly, there is a less severe response at 181.3 MHz, which is in specification when the actual ETS 300 113 level of +70 dB interferer is applied.

Conclusions

A Bit Error Rate test system for a GFSK - based radio has been described. This has involved the use of a data acquisition card in a PC to generate the test modulation source and to digitise the baseband output from the receiver. Demodulation software has been written on the PC to enable the received bitstream to be extracted and the Bit Error Rate to be calculated. The system has successfully been used to test and debug a radio during its development phase.

References

1. European Telecommunication Standard : ETS 300 113, June 1996, "Radio Equipment and Systems (RES); Land Mobile Service; Technical characteristics and test conditions for radio equipment intended for the transmission of data (and speech) and having an antenna connector"

Acknowledgements

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