The RF Development of a Multi-band GSM Test Set

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This article describes a multi-band GSM test set that has been developed by Plextek Ltd. The test set was designed to allow testing of GSM/EDGE mobile handsets and is based around the requirements of 3GPP TS51.010-1 Annexe 5, but is flexible enough to be customised to meet other requirements.

Architecture

A simplified block diagram of the GSM test set is shown in Figure 1. It comprises a pair of identical two-channel transceiver modules and a front-end combiner module . This configuration allows the testing of a single mobile (e.g. handset, PC card, etc.) as it hands over from one base station to another. The test set is able to simultaneously monitor the current channel, the alternative (next) channel and two interfering channels.

The combiner module (shown in Figure 2) forms the main interface between the unit under test and the transceivers. The test port on the combiner can handle RF input powers up to +45dBm and has built-in protection against DC voltages up to 500V.

The input signal from a handset to the test port of the combiner is split into 4 parallel paths (one to each receiver). Each signal is attenuated by 25dB prior to the receiver input. When the transceiver is in transmit mode, the attenuation between the output of a transceiver and the test port of the combiner is switchable between 25dB and 55dB. The test set needs to provide a signal back to the handset at a level that covers the range the handset would be expected to receive under normal operation. This means that the signal level at the output of the transceiver may be in the range of -20dBm down to -110dBm and so having a 30dB switchable attenuator at this point allows for some improvement in the isolation between the combiner unit and each transceiver.

Frequency Coverage

The test set covers all 5 of the currently allocated GSM operating bands. Preselective filtering within the combiner unit, in both the transmit and receive paths, covers the following bands:

- 450 MHz - 496 MHz (GSM 450)
- 824 MHz - 960 MHz (GSM850 and GSM900R)

- 1710 MHz - 1990 MHz (GSM1800 and GSM1900)

Each of these bands is software selectable and the selection of any band automatically configures the transceiver to the same band.

Transceiver Module

Each transceiver module (shown in Figures 3 and 4) contains 2 receiver-transmitter pairs. A three stage conversion architecture is used and each receiver and transmitter has its own set of synthesisers. This means that for the complete module there is a total of 12 separate, synthesised local oscillators (LOs). Adequate isolation between each individual transmitter and receiver chain is vital. This is primarily achieved by detailed attention to layout, but also by way of the compartmentalisation of individual areas and the use of a machined screening wall. This screening wall is fitted to both sides of the PCB and also shields the radio circuitry from the digital processing. All RF interfaces and the serial port are present on the front face of the unit (shown in Figure 4), with only the power supply connections coming in via the backplane.

The receiver is required to take in a signal within the range -20dBm to +45dBm and so the input IP3 of the receiver varies between 0dBm and +30dBm, depending on the amount of attenuation switched in to the signal path. Post combiner filtering is performed by way of a bank of switched filters. The GSM450 and GSM850/900R path filtering is realised using lumped element filters whilst the GSM1800/GSM1900 path filtering is realised using coupled ceramic co-axial resonator filters (see Figure 3). The triple down conversion architecture has a final IF at 16.2MHz. Additional filtering is realised at the two preceding IFs using combinations of standard SAW filters. All four IF outputs of the complete test set are maintained at a level of +10dBm to provide full scale inputs to the ADCs interfacing to the back-end signal processing, which ultimately confirms correct operation of the unit under test.

The transmitter IF input is also at 16.2MHz and this is up converted by way of a triple conversion to generate the required output frequency. As with the receiver, IF filtering is performed by the use of SAW filters with final filtering being carried out using the same switched path technique, with GSM1800 and GSM1900 filters constructed using ceramic resonators. The output power level of the final PA stage of the transmitter is variable between +13dBm and -52dBm. This final PA is followed by a variable attenuator stage within the transceiver (with variable loss between 2dB and 33dB). Following this there is the 0dB / 30dB switched attenuator in the combiner unit mentioned previously. The overall output at the test set can therefore be varied in 2dB steps, to an accuracy of < ±1dB, from -110dBm up to -20dBm.

Synthesiser Design

The synthesisers form one of the most critical aspects of the design, as local oscillator phase noise adds phase uncertainty to the phase modulated signal passing through the transmitter and receiver. The first step in achieving the lowest possible phase noise for this application was to select a frequency plan that allowed the use of the highest possible comparison frequencies. A relatively fine channel stepping resolution (200kHz) was also required, which suggested that the use of a fractional-N synthesiser may be the best approach, as a comparison frequency that is higher than the channel step would be possible. However, evaluation of commercially available fractional-N synthesiser ICs indicated that the levels of the fractional and reference spurs were too high and led to the use of a standard integer-N type part.

The synthesisers made use of very low noise VCOs from Z-Comm and Micronetics, coupled with the Analog Devices AD41XX series synthesiser ICs. This ensured that the composite phase noise contribution of the synthesisers to the GSM signal was low. Figure 5 shows a plot of the combined response of the phase noise of all three local oscillators used in the transmitter. Knowledge of both the phase tracking algorithm of the demodulator (GMSK for standard GSM/GPRS and 8-PSK for EDGE) and the digital filtering implemented as part of the signal processing allowed the combined response of the LOs to be optimised to give the lowest possible contribution to the phase error. Measured results using a Rohde & Schwarz FSIQ show the overall phase error due to the combined performance of the complete transmitter to be much less than 1° RMS with an added EVM of less than 4% RMS.

Implementation

The receivers, transmitters and synthesisers were designed using commercial off the shelf (COTS) components to help reduce costs and ensure availability. This includes the use of many gain block amplifiers from suppliers such as Mini-Circuits, RFMD and Watkins-Johnson and the use of a frequency plan allowing SAW filters at GPS frequencies to be utilised. This use of off the shelf components results in the DC power requirement and thermal dissipation being significant, but allowed short development timescales and provide a flexible solution that can be readily customised to address customer specific requirements.

Calibration of the complete test set-up is performed using a pair of transceivers and a single combiner unit. These units are temperature cycled and the gain adjustments stored in the on-board flash memory of a microcontroller. Currently this process is semi-manual, but provision has been made to implement a fully automated calibration procedure. Once calibrated, the gain of the transmitter is adjustable in 2dB steps to an accuracy of $< \pm 1$dB. This allows accurate control of the output power at the test port in the range of -110dBm to -20dBm. The receiver is also calibrated to have a gain accuracy equal to that of the transmitter over an input range level of +46 dBm to -20 dBm (at the test port).

The interface between the host and the combiner/transceiver units is formed using a microcontroller. This decodes the input commands to the unit and re-configures the transceiver via an interface to a Xilinx FPGA. This FPGA then acts to re-program synthesisers, set gains according to calibration tables, etc. The interface firmware contained within the micro controller may be customised to meet the requirements of any host machine.

To allow for synchronisation of several transceiver and combiner units, provision has been made on the front panel of the units for the 10MHz internal OCXO reference to be output as well as an internal 65MHz clock. The 10MHz may also be locked to an external source or other transceiver unit by the use of an external reference input (also located on the front panel) which will automatically detect an external reference source and use it to phase lock the internal reference OCXO.

Each transceiver unit takes a total of 40W from ±12V and +5V and so, due to their compact size, they dissipate a significant amount heat and require forced air cooling. The combiner unit takes virtually no DC power (< 0.5 W) but also requires forced air cooling as it has the potential to dissipate the heat generated by the attenuation of high input signal at levels (up to +45dBm) by 25dB.

Transfer of heat from the majority of ‘hot’ components is managed by mounting them either on or next to contact areas of the metal casework. This decreases the possibility of large thermal gradients across areas of the PCB. Monitoring of the temperature of the PCB is carried out by the use of 3 temperature sensors across its surface. Tests have shown that the PCB maintains an even temperature profile thanks to these thermal considerations, allowing for accurate control of the gain of each transmitter and receiver by way of the calibration tables stored in the flash memory within the micro controller.

Summary

A low phase noise, multi-band GSM test set has been designed and demonstrated. It is suitable for the testing of GSM/EDGE mobile units, can process four signals in parallel and covers all five of the currently allocated GSM frequency bands. The test set is designed to support EDGE modulation and the total phase error caused by the integrated effect of the phase noise of all LO signals is less than 1° RMS with an added EVM of less than 4% RMS. The test set will be offered as a finished product or on a license to manufacture basis. In both cases the test set can be customised to meet specific client requirements.

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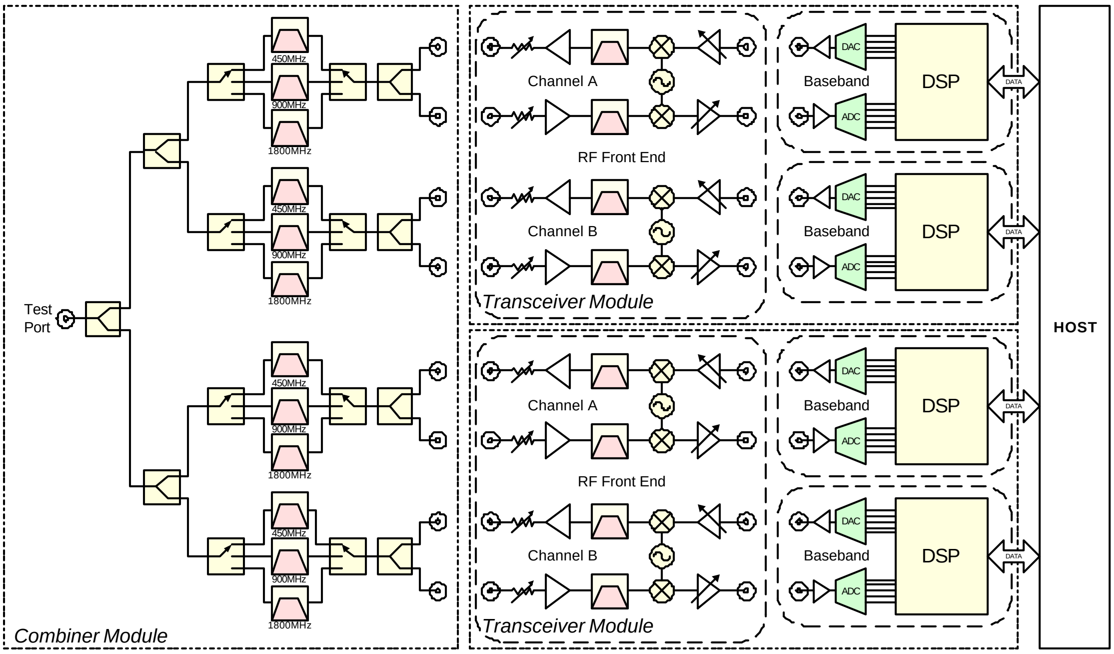

Figure 1: Test platform system outline

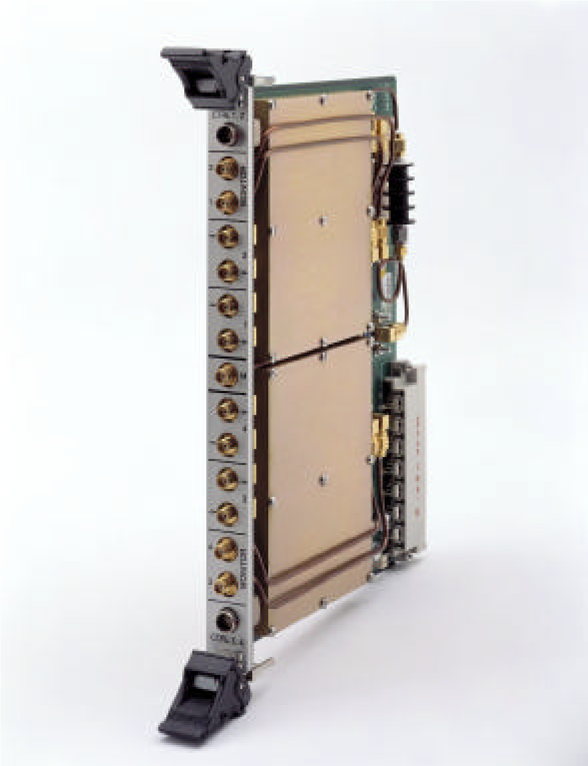

Figure 2: Combiner module

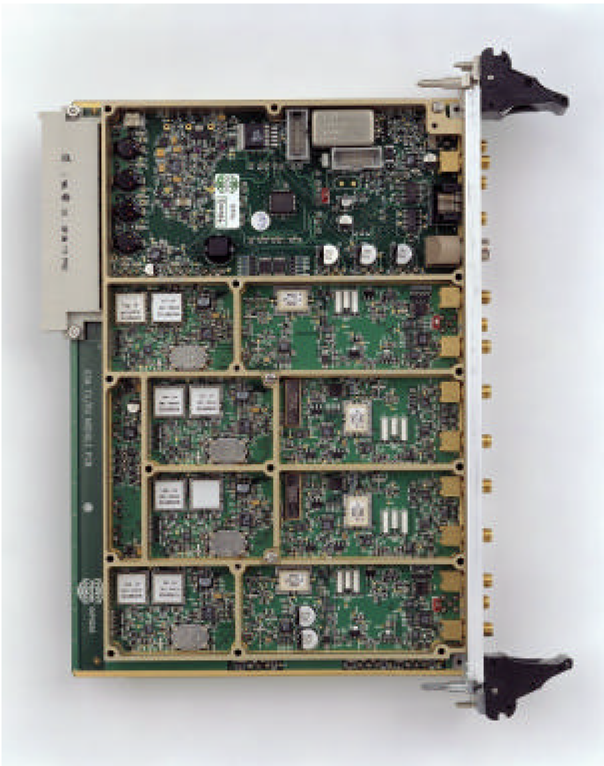

Figure 3: Transceiver module, showing ceramic filters and dual VCO synthesisers

Figure 4: Transceiver unit front panel

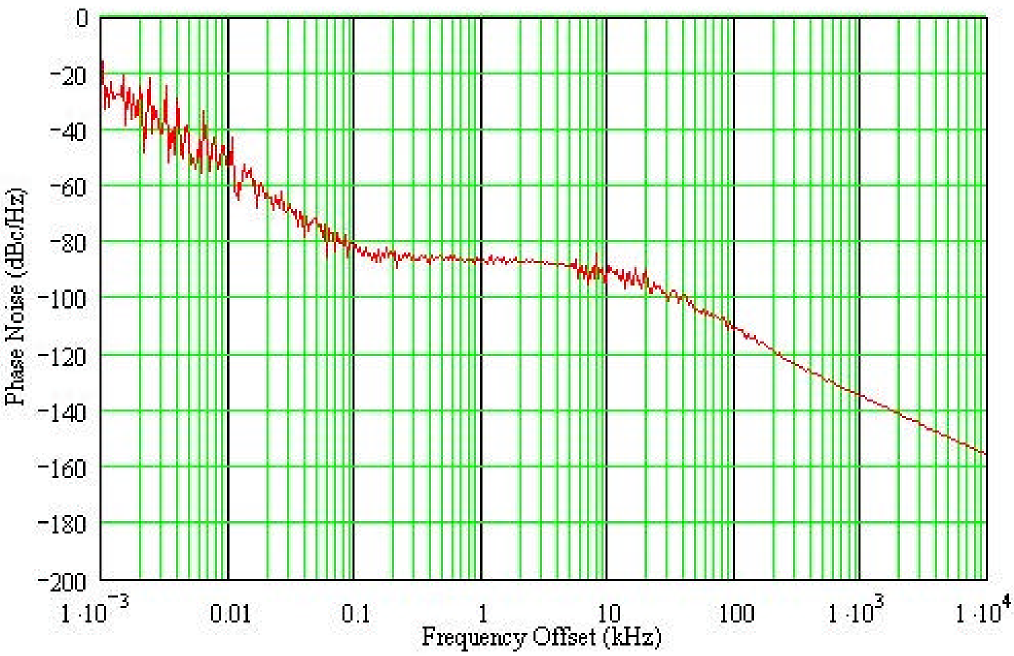

Figure 5: Measured composite transmitter phase noise