White Paper

Millimeter Wave Technology and Test Instrumentation for V-E Band Applications

Abstract

Broadband wireless backhaul technologies have become a key element of cost-effective high speed wireless networks. With the explosive growth in wireless data traffic, telecom companies need to deploy multi-gigabit backhaul links. With wide-bandwidth, 71-76GHz and 81-86GHz, available in the lightly licensed E-Band and advances in semiconductor technology, point-to-point E-Band links have gained momentum.

Infineons's highly integrated transceiver family BGT70/80 covering 71-76GHz and 81-86GHz is housed in eWLB plastic package. The chips have been designed to support spectrally-efficient modulation, up to QAM64 with a bandwidth up to 1GHz.

An E-Band link at 86GHz is realized using Infineon's BGT80 transceiver and Agilent's M8190A AWG and Infiniium series Oscilloscope. QAM64 is used to realize this link with data rate of 3Gb/s.

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1 Application Areas

As more and more users are going “online” from mobile devices and use high bandwidth services like high-definition video streaming, high-quality video conferencing, audio video downloads and gaming; the demand for faster wireless broadband connections is growing. The evolution of 4G-LTE networks to meet this demand and to deliver performance/services as per expectations of the end user, has led to many challenges. One of these challenges is to backhaul the data from Base Stations to the Core Network of carriers. To overcome this challenge there is a need to have reliable high Data Rate >1Gb/s communication links. With the advances in mmWave technology there is a trend to shift from traditional backhaul i.e. Optical and Microwave links to mmWave point-to-point links which over long term can offer the Network operators price performance advantage. There is a 10GHz of bandwidth available in E-Band, 71-76GHz and 81-86GHz, which is to be used for connecting the cellular base stations to the core network of operators. There are other applications fields available around the unlicensed 60GHz band such as WiGig (WiFi) and the planned 57-64GHz band for short distance backhaul in the upcoming Small Cell telecommunication network. In Figure 1 a rough schematic shows how the Infineon BGT70 and BGT80 Transceivers can be used in the example of such a mobile communications backhaul application.

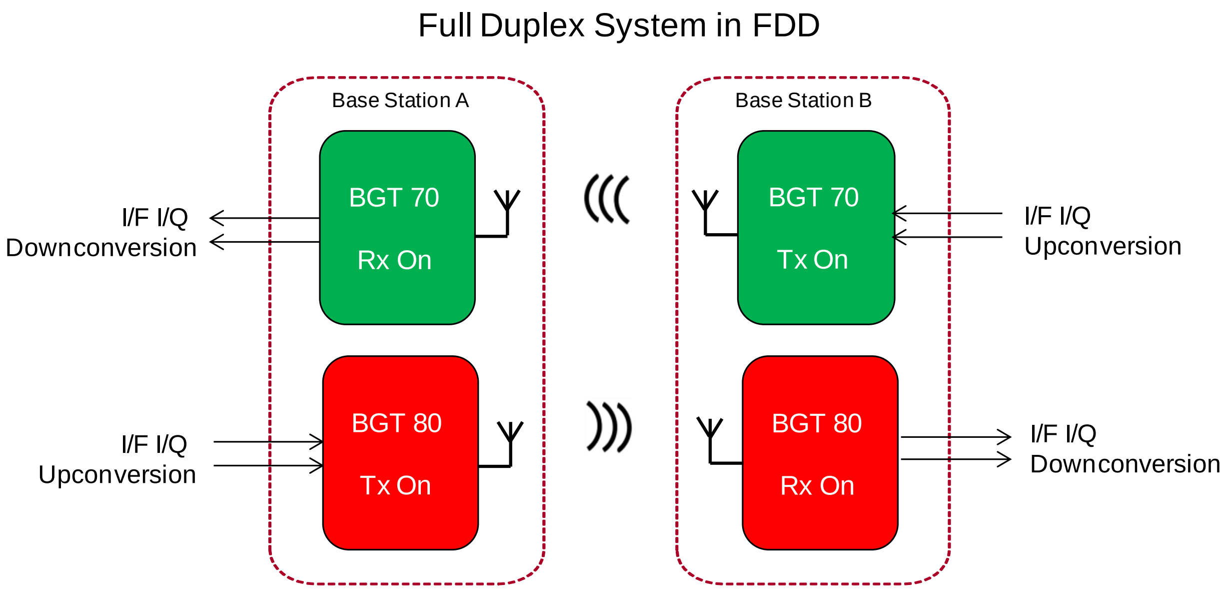

Figure 1: Typical application scenario in Mobile Backhauling using mmWave point-to-point link (can also be a TDD system)

With the latest semiconductor materials and new technologies, such as Infineon's B7HF200 SiGe:C Bipolar Technology, the realization of such millimeter wave devices becomes more and more affordable. Infineon's mm-wave transceiver families cover 57-64GHz (BGT60), 71-76GHz (BGT70) and 81-86GHz (BGT80) bands. In order to evaluate the link quality one would need the proper test and measurement instruments. For the three main parts of a communication link: transmitter, signal path, receiver, we will be looking for a generator, signal path emulator and an analyzer type of instrument. Agilent Technologies offers a wideband Arbitrary Waveform Generator M8190A for signal generation and signal path emulation purposes and High Performance Infiniium Series Oscilloscopes with Vector Signal Analysis 86901B software.

Let's evaluate the use of the introduced test and measurement equipment using Infineon's BGT80 E-Band transceiver chipset. Its block diagram can be seen in Figure 2.

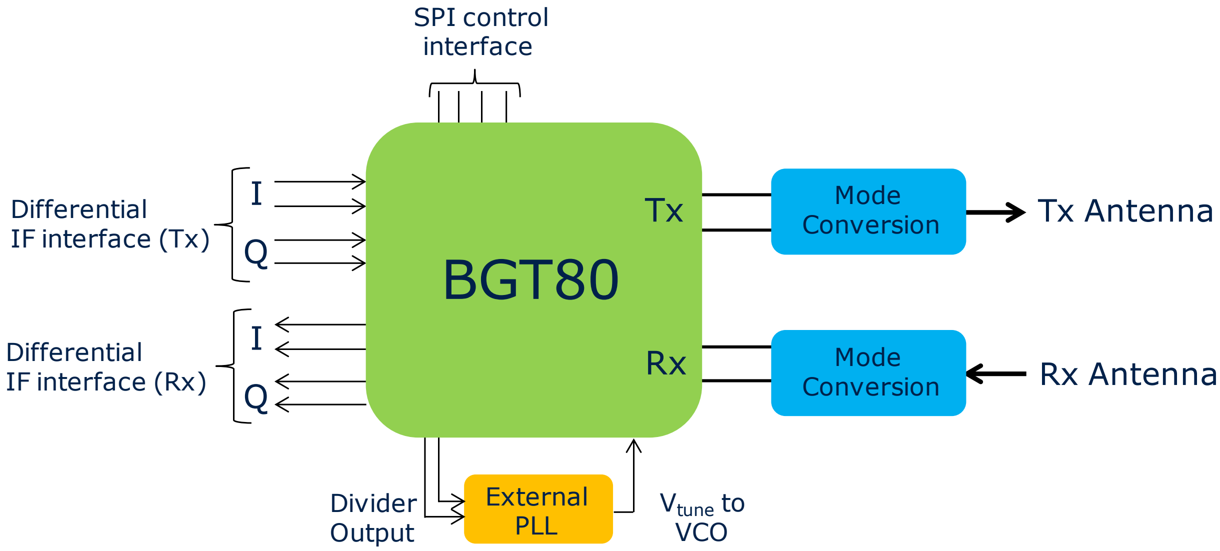

Figure 2: Block Diagram of Infineon's BGT80 (81-86GHz) Transceiver chipset

2 BGT80 Evaluation Board

BGT80 is a highly integrated packaged (eWLB) E-Band transceiver chip with excellent Phase Noise performance. It has integrated temperature, power detectors and easy to use SPI interface for Power control, Mode Switching (Tx or Rx), Calibration. The integrated power detectors enable power control in a feedback loop as well as LO rejection and image calibration. Infineon's BGT80 Evaluation board, as shown in Figure 3, provides all the interfaces to make quick link testing and has on board PLL. Along with Agilent's M8190A AWG and Infiniium Oscilloscope, the evaluation of BGT70/BGT80 transceivers is an easy procedure. Table 1 below also highlights the performance parameters at chip level.

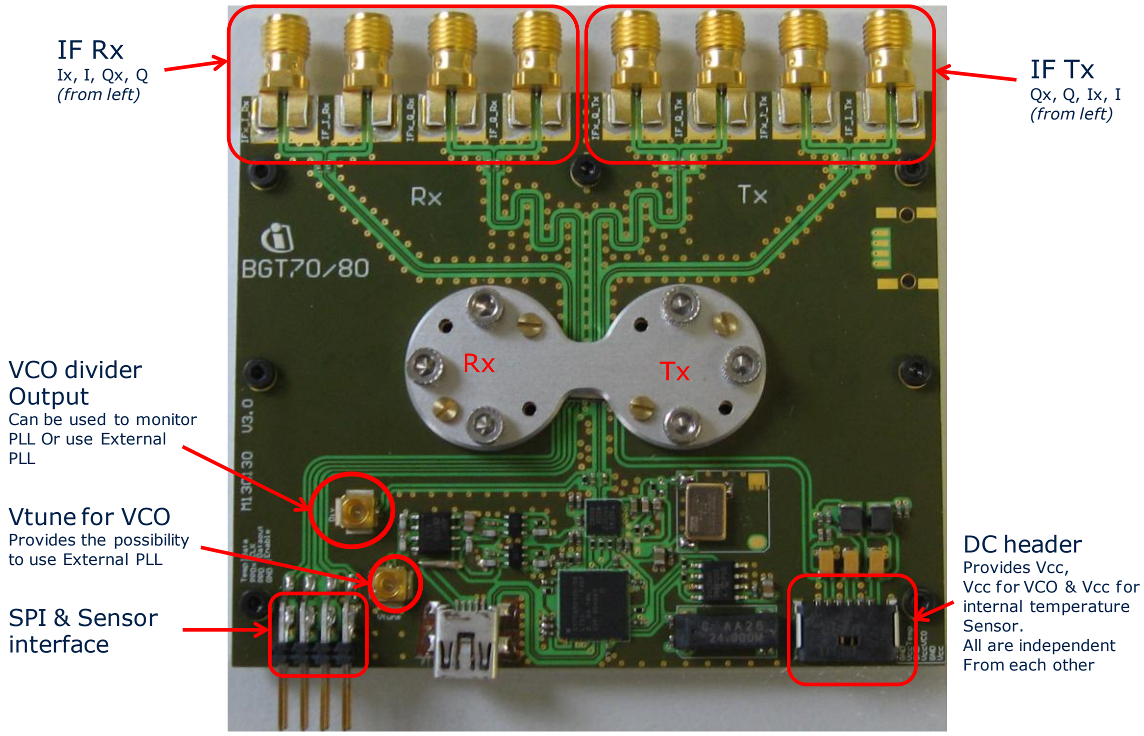

Figure 3: BGT80 Evaluation board used in link testing

BGT80 (81-86GHz) Transmitter Specification		
Saturated Output Power	12	dBm
Phase Noise @ 100kHz/1MHz offset	<-80/-100	dBc/Hz
Output IP3	20	dBm
Noise Floor at Tx output	-130	dBm/Hz
Power Consumption in Tx Mode	1.5	W
BGT80 (81-86GHz) Receiver Specification		
Conversion Gain	20	dB
Input 1dB Compression Point	-15	dBm
Noise Figure DSB	9	dB
Power Consumption in Rx Mode	1.1	W

Table 1: Infineon BGT80 Transceiver Performance Specifications

3 Test Requirements and Solution Proposals

To test a transceiver device one would need a simulated transmitter and/or a simulated receiver. Ideally both should be flexible enough to generate real world distortions on the source side and compensate them on the sink side. With Agilent's M8190A High Performance Arbitrary Waveform Generator, working at 12bit and 12 GSa/s or at 14 bit and 8 GSa/s, the user has all the freedom in crafting the needed waveform. This would be the proposed test source for the envisioned experiment. On the analyzer side Agilent offers a broad portfolio of Infiniium series Oscilloscopes going up to 63GHz of real time frequency bandwidth. The solution is round out by the software package consisting of MATLAB® support for the signal creation and 89601B Vector Signal Analysis software for signal analysis. Figure 4 illustrates this comprehensive setup.

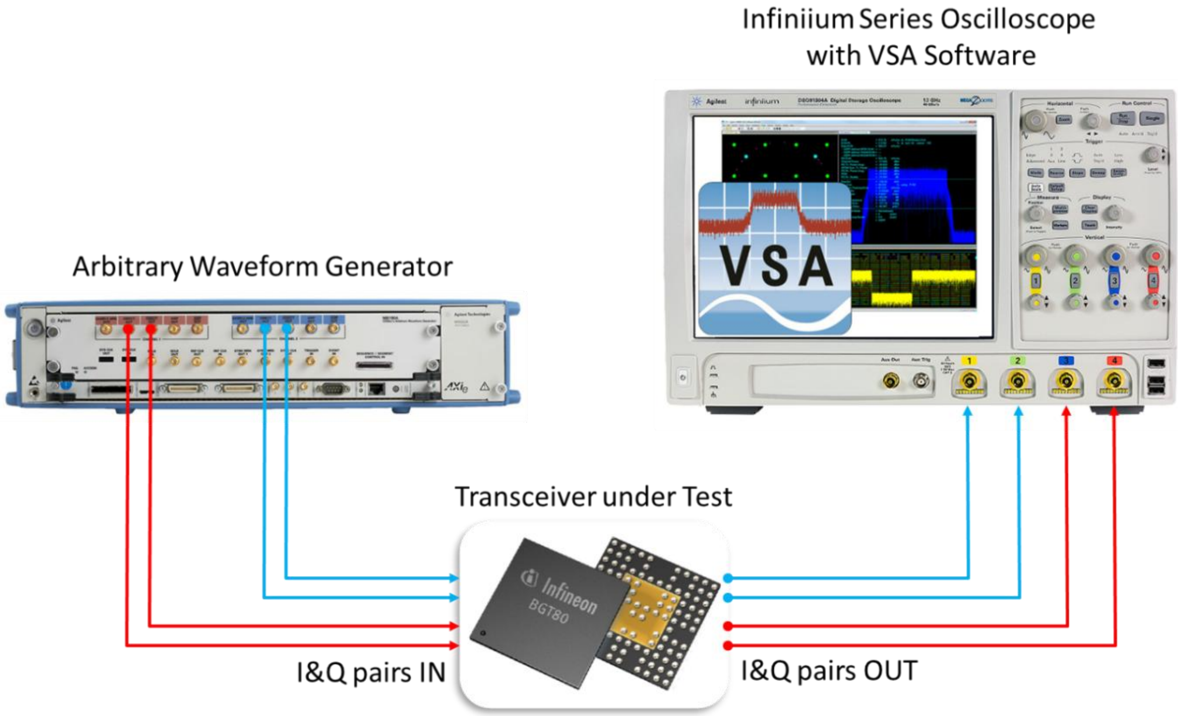

Figure 4: Basic Test and Measurement Setup for Transceiver Test

4 Measurements

It is recommended to start off with a simple modulation scheme such as QPSK and advance to higher orders like QAM64 step by step. The reason for it lies in the fact that the operator needs to find its sweet spot to achieve the best performance results. This sweet spot requires tuning in amplitude/phase mismatch, carrier feed-through, side band suppression and inter-modulation performance. The LO leakage and sideband leakage are direct results of amplitude and phase imbalances. LO leakage could be caused by DC offset in the I and Q signal paths or incorrect bias points of the modulator. One can reduce it by optimizing the bias voltages of the IQ modulator. Intermodulation distortions come from amplifier non-linearities. In other words the input signal can have a too high voltage swing which causes the amplifier to leave the linear operation range of its transfer function. This can be improved by regulating the input voltage of the signal.

With differential outputs of Infineon's BGT80 transceiver it is needed to have an instrument able to receive differential signal and convert them to single ended measurements. In our example we use a 4-channel high performance oscilloscope. Internally the software calculates the difference between the I and $\bar{I}$ signals creating a logical 1st channel, or the I-channel. The same happens to Q and $\bar{Q}$ signals on the other two oscilloscope channels creating the logical 2nd channel, or the Q-channel.

In Figure 5 you can see a signal generated by an AWG, up-converted by Infineon's BGT80, transmitted over the air in an 86GHz link, down-converted by the same type of transceiver chip and analyzed by an oscilloscope with vector signal analyzer software.

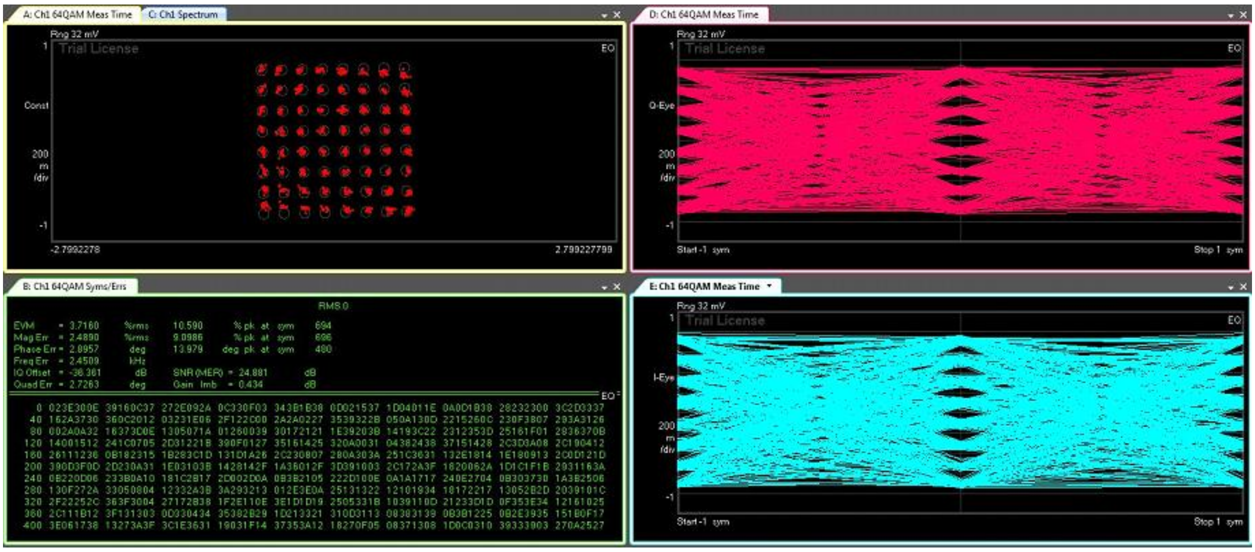

Figure 5: 64-QAM Constellation with 3GSymb/s and a Q-eye respectively I-eye diagrams on a 86GHz communication link

5 Tweaking and Tuning

The outputs of the modulators are normally designed to drive high impedance loads because of the limitations in electrical current availability. Therefore additional care needs to be taken when connecting an oscilloscope to the receiver side of the transceiver chip. The oscilloscope input impedance needs to be set to 1MΩ. If this setting is not possible, you might want to consider using high impedance probes or operational amplifier circuitry to transform the impedance values.

Ideally the full digital-to-analog converter (DAC) voltage range should be used to achieve best signal quality. In our case it can vary between 350mVpp to 700mVpp at the M8190A Direct DAC output. Tuned for low power consumption, the transmitter devices usually work with input voltage levels around 100mVpp and less. In order to reach these levels without limiting the DAC resolution and without lowering signal quality, it is recommended to run the DAC at the lowest possible voltage range and use attenuators to adjust the signal levels to the desired range.

It is also recommended to work with matched cable pairs on the receiver and on the transmitter side. It will reduce time delay differences between the single signal paths and with that unwanted spurious emissions.

With all the described precautions, the lab engineer will find an ideal operating point of the modulator to achieve best possible linearity resulting in highest EVM performance.

6 References

- www.infineon.com/backhaul
- www.agilent.com/find/M8190
- www.agilent.com/find/scopes
- www.agilent.com/find/vsa

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