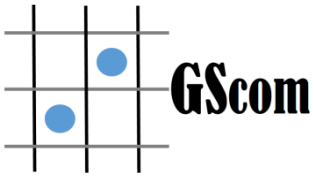

Broadband Wireless Communication Technology Development Proposal

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1 Introduction

With the advent of WiFi, WiMax, and LTE technologies in 4G networks, the small cell business grows explosively. With the 4G technologies, the coverage range of each small cell is reduced, the number of small cell is increased, and the data throughput is increased significantly. As 4G capabilities are added to 3G networks, cell site backhaul and aggregation network requirements rises from hundreds of megabits/second into the gigabits/second of capacity range.

High speed data, high spectral efficiency, and reliability are getting more and more important technical decision factors in a 4G communication business. GScom has developed in MATLAB a broadband wireless 1024-QAM modem for Gigabit data communication and a variety of wireless communication core component technologies. GScom is working on development of the wireless 1024-QAM modem product using custom designed Field-Programmable-Gate-Arrays (FPGAs).

GScom's wireless communication core technologies and 1024-QAM modem address a wide variety of system-level challenges in wireless communications, including performance with very high speed (up to Giga bps) data communication in a broadband spectrum ranging from cellular band frequencies up to microwave or millimeter wave band frequencies.

GScom's wireless 1024-QAM modem yields the most reliable and the best performance in a broadband wireless backhaul communication channel in the small cell or macro cell communication network systems.

GScom has two objectives in this proposal to you: The first is to get your investment to secure the broadband wireless 1024-QAM modem product using FPGA. The second is to sale our technology license or to provide our technology development consulting service to you.

Under the broadband wireless 1024-QAM modem development program, GScom has two development stages in the development program: The first is to secure the modem using FPGA and the second stage is to secure the modem using ASIC. In this proposal, we will deal with the modem development using FPGA. Under our estimation, GScom needs about 123 MM(man-months) and 2M USD to secure the commercial product of the broadband wireless 1024-QAM modem about 18 months after the activation of the development project.

For the technology license or technology consulting service program, GScom provides our customers with system solutions and consulting services for leading-edge communication systems. GScom has available a broadband wireless 1024-QAM modem for Gigabit data communication providing a broad spectrum of wireless communication core technologies and intellectual properties. GScom's innovative technology leadership combined with our innovative design services experience enables our customers the ability to rapidly and effectively innovate, differentiate and win in their markets.

2 Wireless Communication Backhaul Market Trend

With the advent of smart phone in along with 4G systems, wireless networks evolves to next-generation packet architectures capable of supporting enhanced broadband connections. Simple text messaging and slow email downloads are being replaced by high-speed connections that support real time video, streaming music, and other rich multimedia applications. The 4G and beyond wireless networks will approach the broadband speeds and user experience now provided by traditional DSL and cable modem wire-line service.

From the wireless operator's perspective, the 4G and beyond systems are more efficient at using valuable wireless spectrum. These spectral efficiency improvements support new high-speed services, larger numbers of users, and will generate more revenues with a given frequency spectrum.

With the advancement of the wireless communication technology along with its application, a wide range of the carrier frequency spectrum is used (for example, from cellular band to millimeter wave frequency band) due to the availability of the spectrum and its cost. In general, the higher carrier frequency is used, the higher phase noise is generated.

GScom has developed a broadband wireless 1024-QAM modem, for high spectral efficiency, which can support a wide range of carrier frequency spectrum (from cellular band to 80GHz).
The modem has excellent performance:

1. Within 1-2dB away from the theoretical BER (bit error rate) curve in AWGN
2. 8-10 dB coding gain from Forward Error Correction (with using LDPC on 8640 code length).
3. very robust to a phase noise (6-8dB performance improvement).

3 Broadband Wireless 1024-QAM Modem

3.1 Introduction

GScom developed in MATLAB a broadband wireless modem to achieve Giga bps (bits per second) range high speed data communication for both microwave and mm-wave radio systems. The broadband wireless modem is a single carrier QAM modem for spectral efficiency and can be used in broadband wireless communication systems for fixed wireless backhaul communication, cellular access networking, or small cell backhaul communication. The broadband wireless modem supports modulation levels up to 1024-QAM and is very robust to phase noise, developed for point-to-point or point-to-multi point microwave and mm-wave radio systems. The broadband wireless modem achieves the high speed data communication capability through advanced technology development in the modulation, coding, signal processing, and system operation areas.

3.2 System Fratures

The main features of the 1024QAM Modem IP Core are listed below:

- Modulation: 4QAM/16QAM/64QAM/256QAM/1024QAM
- Bandwidth: 28/56/112MHz
- Up to 22.96/45.92/91.84 MSym/second
- Real time Gray code mapper/De-mapper with very low latency LLR decoding
- LDPC (low density parity check) codec;
    - Code length: 4320/8640 bits, & Coder rate: 0.5/0.75
    - Architecture Aware Parallel TDMP architecture
    - Horizontal and Vertical Partitioned LDPC
    - Optimized node degree distribution LDPC
- Fractional spaced DFE (decision feedback equalizer) combined with carrier recovery.
- Sampling rate: 200MHz
- Shape Filter: Squared-Root-Raised-Cosine with 64 taps
- Roll-Off factor: 18%
- Internal BER tester

3.3 Performance

We carried out the system performance simulation of the broadband wireless modem on 4QAM, 16QAM, 64QAM, 256QAM and 1024QAM modulation QAM levels inserting varying SNR levels of additive white Gaussian noise, along with phase noise masking levels obtained from one of tier-1 backhaul equipment vendors. The following table shows the performance improvement of the modem due to the LDPC codec architecture chosen and the phase noise mitigation from the combination of the DFE (decision feedbak equalizer) and carrier recovery.

LDPC coding gain with reference to 1e-6 BER

	4QAM	16QAM	64QAM	256QAM	1024QAM
AWGN	8 dB	6 dB	5 dB	6 dB	6 dB
PN+AWGN	6 dB	5 dB	1 dB	0 dB	0 dB
PN+AWGN w/DPLL	6 dB	6 dB	5 dB	6 dB	4 dB

NOTE: BER=bit error rate, AWGN=additive white Gaussian noise, PN= phase noise
DPLL=digital phase locked loop

The broadband wireless modem provides very reliable functionality while being very robust to any kind of noise such as AWGN, phase noise, etc.

4 Business Proposal

GScom has two business models: The first is to make and sale the broadband wireless 1024QAM modem product using custom designed Field-Programmable-Gate-Arrays (FPGAs). GScom developed in MATLAB the broadband wireless 1024QAM modem. GScom needs to get investment money to implement the modem into the FPGA hardware, test, and make it a commercial product as soon as possible. The second is to sale our technology license and/or to provide our technology development consulting service to you.

4.1 1024-QAM Modem Development

4.1.1 Summary

GScom developed in MATLAB a broadband wireless modem for Gigabit data communication for both microwave and mm-wave radio communication systems. GScom is working on development of the wireless 1024-QAM modem product using custom designed Field-Programmable-Gate-Arrays (FPGAs). GScom conducted the project analysis for the commercial product. According to the project analysis, GScom needs 2M USD to make the commercial product of the 1024-QAM modem within 18 months after the kick-off the project. GScom is looking for investors or business partners to secure the investment money of the $2M USD. GScom proposes to have a business talk if you are interested in securing a very reliable and economical system solution for Gigabit data communications.

4.1.2 Baseline Design

The baseline of the broadband wireless 1024-QAM modem has been developed, verified in MATLAB, and is based on the digital baseband solution as documented in the modem system document [1].
If you want to change important system specification from the initial design we can discuss with you before we implement them in the commercial product.

4.1.3 Project Tasks

This section provides an overview of all required project tasks, together with an assessment of the effort required.

TASK 1: Project Management

- project documentation
- managing resources
- highlighting and resolving critical issues

TASK 2: System Architecture Design

- preliminary high level design of all blocks, enabling kickoff of detailed design activities
- interface specifications

TASK 3: Prototype Board Design

This task will design the prototype board for the broadband wireless 1024-QAM modem, including the Input Interface, Output Interface, FPGA and Operator physical interface.

Prototype board design:

a. input at 140 MHz IF
b. bandwidth selectable up to 112 MHz
c. modulation selectable from 4QAM up to 1024 QAM

TASK 4: Design of the Modem Core Blocks

The main functionality of the modem is implemented as IP Core on the target FPGA. In this task, GScom shall design and verify all functional blocks required for the final solution. Analysis and tradeoffs shall be made using both MATLAB simulation models and where necessary by implementation in Verilog and downloading onto the target FPGA on the prototype boards. The functional blocks of the modem are described on Figure 6 & Figure 7 in the modem system document [1].

TASK 5: Software Design

- Physical control software
- MAC/Ethernet OAM software
- Network communication software

4.1.4 Project Plan, Milestones and Deliverables

4.1.4.1 Project Plan

It will take 18 months to make the broadband wireless 1024QAM modem product available in the market after the kick-off the project. Figure below shows the top level planning of the tasks required to complete modem development project.

4.1.4.2 Milestones

- Systems Design (Fixed Point): by 10 month after kick-off
- Hardware Design: by 14 month after kick-off
- Lab Test (Software Design): by 14 month after kick-off
- Field Test : by 18 month after kick-off

- Interim Design Review Meeting I: by 10 month after kick-off
- Interim Design Review Meeting II: by 14 month after kick-off
- Final Product Meeting: by 18 month after kick-off

4.1.4.3 Deliverables

- Regular meetings with investors: nominally every month
- Minutes of meetings with action items: within 1 working day after each meeting
- All relevant technical documentation, including design tradeoffs, performance results etc.
- Full documentation for presentation at the interim Design Review Reeting , at the latest one week before the meeting date

4.1.5 Financial Proposal

4.1.5.1 Project Budget

The project budget consists of employee salary, design tool license fee and test equipment rental fee, prototype board production fee, and office rental and maintenance fee. The major part of the project budget will be allocated to employee salary. Based on Section 4.1.5.1. project schedule, Modem development activities will require in total 123 man-months for the development of commercial broadband wireless 1024QAM modem products.

Summary of the budget is as follows (refer to the document attached for detail) [2]:

- Employee salary: 1,350K USD
- Design tool & test equipment rental fee: 310K USD
- FPGA prototype board (3 set): 60K USD
- Office rental and maintenance fee: 180K USD

Total project budget required for 1024QAM modem development: 1,900K USD

4.1.5.2 Change Management

Should significant deviations occur in project activities due to the amendments in initial specification, subsitution of tasks, timelines and budget or due to any other objective circumstances, GScom will immediately inform Investors about such deviations. In such cases, parties will seek in good faith ways to address deviations and may introduce amendments to the negotiated terms and conditions if this deems necessary.

4.1.6 Project Organization

Project is functionally organized around the positions indicated in table under Section 4.1.5.1. Administrative management is performed by Project/Account Manager, R&D task leadership is carried out by VP of Systems Engineering & VP of Hardware Engineering.

Project/Account Manager for this project is Dr. Sanguoon Chung (schung@gs-communication.com, Ph: +1-858-776-0290).
VP of Systems Engineering is Dr. Stash Czaja (+1-619-857-0141).
VP of Hardware Engineering is Mr. Steve Meire (ph: +1-760-445-9382).

4.2 Technology Licensing

GScom has developed in MATLAB a broadband wireless 1024-QAM modem for Gigabit data communication systems, along with a variety of wireless communication core component technologies, or intellectual properties (IP), which are available for purchase and/or licensing. GScom's wireless communication core technologies and 1024-QAM modem address a wide variety of system-level challenges in wireless communications, including performance with very high speed communication in a broadband spectrum ranging from cellular band frequencies up to microwave or millimeter wave band frequencies.

The modem provides very reliable, stable, and excellent performance in any channel impairment conditions including tough phase noise environments. The modem has excellent performance:

1. Within 1-2dB away from the theoretical BER (bit error rate) curve in AWGN
2. 8-10 dB coding gain from Forward Error Correction (with using LDPC on 8640 code length).
3. very robust to a phase noise (6-8dB performance improvement).

The wireless communication technologies for sale or licensing are as follow:

■ Broadband wireless 1024 Modem (as a system package solution)

The broadband wireless 1024-QAM modem is equipped with a powerful LDPC codec and advanced Decision Feedback Equalizer (DFE) which is combined with a Carrier Tracking Circuit. The modem supports 4-QAM, 16-QAM, 64-QAM, 256-QAM and 1024-QAM modulation-rates, combined with LDPC code rates of 0.5 and 0.75, selected according to channel conditions. The modem also supports large dynamic range (100dB) Automatic-Gain-Control (AGC), power control, and Adaptive Coding and Modulation (ACM).

The modem is designed to perform high speed data communication with reliable quality in any harsh communication channel environment and to support the usage of any carrier frequency from the cellular band carrier frequency up to the millimeter-wave band carrier frequency (80 GHz). Performance testing of the modem shows the modem to be within 1~2 dB or 3~4dB away from the theoretical BER curve, dependent upon the modulation technology and channel condition used.[1]

■ Communication Core Component Technologies

Technology used in wideband communication systems require high coding/modulation gain, very short latency, and real time processing as much as possible. GScom has developed these core component technologies for application in Gigabit-class wireless communication systems. Following are some of the typical core component technologies developed by GScom.

◆ LDPC (Low Density Parity Check) Codec [3]

LDPC is the one of the most powerful linear block codes in terms of performance (coding gain). LDPC decoding algorithm is inherently parallel which is attractive for high-speed applications. GScom has developed a custom LDPC codec (encoder/decoder) using the following LDPC architecture and technologies:

- Architecture aware LDPC for low complexity and fast encoding
- Architecture aware parallel TDMP for low complexity and fast decoding.
- Horizontal & vertical partitioning LDPC for low complexity and fast decoding.
- Optimal node degree distribution LDPC for best performance with optimum complexity.
- Achievement of 8~10 dB coding gain with a code length of 8640 and a code rate of 0.5 in the reasonable SNR ranges for data communication.

◆ Mapper/De-mapper (Slicer) [4]

The Mapper takes the coded bit stream at the output of the (LDPC) encoder and maps each group of m bits into one of the M(= 2^m) signal constellations. The De-mapper receives the demodulated symbols from the demodulator and converts the received symbols into the soft decision values of the corresponding bit stream through a soft decision decoding process.

- **Mapper/De-mapper for QAM from 4QAM upto 1024QAM modulation level.**
  GScom has developed a real-time mapper/de-mapper for various QAM modulation levels.

◆ Equalizer combined with Carrier Recovery [5]

Fading, inter-symbol interference, time varying channel characteristics, large dynamic range of signal to noise ratio (SNR), etc, are major signal impairment factors in the broadband wireless communication systems. Phase noise is also one of the most critical signal impairment factors in wireless communication systems which use high carrier frequencies with high-order M-QAM such as 256-QAM or 1024-QAM modulation technologies.

GScom has developed an advanced fractionally spaced Decision Feedback Equalizer (DFE) which is combined with a carrier recovery circuit. The carrier recovery combined with the DFE is a powerful solution to fight against phase noise through the latency reduction between phase noise estimation and correction. The GScom equalizer yields an excellent performance not only in the white noise but also in the phase noise environment [4].

◆ AGC (Automatic Gain Control) [6]

The signal in a wireless communication channel experiences a large dynamic range of signal variations due to channel conditions, weather conditions, flat fading, and shading effect of the communication environment.
GScom has developed several types of AGC in terms of accuracy, HW simplicity, and reliability based on the following common AGC specification:

- Input signal dynamic range of 100 dB
- Flat fading rate of 100dB/sec
- Output signal level of 20dBm+/-3dB.

◆ Time Tracking (Symbol tracking & Frame tracking)

GScom has developed the symbol synchronization and frame synchronization technologies using a preamble sequence in the acquisition frame, and symbol tracking and frame time tracking using a time Delay Locked Loop (DLL) with the 2^{nd} order Phase Locked Loop (PLL).

◆ ACM (Adaptive Coding & Modulation)

ACM is a communication technology which is used to maximize the communication system efficiency with a given channel condition.
GScom has developed the ACM technology using real-time channel information of the SNR from the equalizer, RSSI from the AGC, and desired range of SNR in the modulation and coding technology. The ACM supports 4-QAM, 16-QAM, 64-QAM, 256-QAM and 1024-QAM modulation rates and LDPC code rates of 0.5 and 0.75.

4.3 Technology Consulting Service

GScom has been working on a wireless backhaul modem and its core technology development over the past three years and has developed a complete wireless backhaul 1024-QAM modem for Gigabit communication.

Each of the founding members of GScom has a minimum of twenty five years of experience working in the wireless communications area for tier-1 wireless communication companies including Nokia, Sony, Samsung, Via Telecom, Infineon, Broadcom and Xilinx.

GScom has a broad background, experience, and expertise in wireless communication system analysis, system design, algorithm design, system partitioning and hardware optimization. The GScom team has a broad spectrum of development experience in the development of a variety of wireless communication baseband system, such as IS-54, HSDPA, HSUPA, LTE, 802.11n, 802.11ac, along with broadband backhaul communication systems. GScom provides consulting services for technology development not only at the systems level but also at the hardware implementation level.

GScom provides technical development and consulting services in the following areas:

1. Product development of wireless communication baseband modems for handset and/or backhaul communication systems.
2. Core component wireless technology development for handset and/or backhaul communication systems.
3. Hardware system development and optimization of the wireless communication technology for handset and/or backhaul communication systems.

5 References

[1] GScom Corp., “Broadband Wireless 1024QAM Modem”
(https://www.gs-communication/whitepapers/Broadband wireless 1024-QAM Modem)
[2] GScom Corp., “Project budget for development of 1024QAM Modem”
(https://www.gs-communication/whitepapers/Project Budget)

[3] GScom Corp., “LDPC System Design”
(https://www.gs-communication/whitepapers/LDPC_Sytem_Design)

[4] GScom Corp., “Mapper”
(https://www.gs-communication/whitepapers/Mapper)

[5] GScom Corp., “DFE & Carrier Recovery”
(https://www.gs-communication/whitepapers/DFE_&_Carrier_Recovery)

[6] GScom Corp., “AGC Design”
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