Highly Integrated Microwave Point-to-point Outdoor Unit Optimized for Ultra High Volume Manufacturing

Jyrki T. Louhi, Hans Somerma, Kari Nikkanen, Markku Koivisto, Nils Nordman, Tero Tuoriniemi, Mika Hirvilampi, Mika Pehkonen, Kari Vepsäläinen, Petri Bergholm, Pasi Ruhanen, Mikael Platan, Jorma Rantiala, Petri Mikkonen, and Jarmo Mäkinen

Nokia Corporation, Nokia Networks, P.O. Box 370, FIN-00045 Nokia Group, Finland

Abstract — **A digital microwave point-to-point radio platform has been developed for the frequency range of 13 - 38 GHz. The most important design requirement was to obtain a radio, which is suitable for high volume manufacturing. This goal was successfully met first, by employing an electromechanical structure, which is easy and fast to assemble, secondly, by using an architecture, which allows a short and simple testing process after assembly, and thirdly, by employing novel circuit designs with a highly integrated microwave module.**

I. INTRODUCTION

Digital microwave point-to-point radios have been used for years to provide the transmission on both cellular and dedicated networks [1]. The benefits of the microwave radios have been widely noticed by cellular network operators, and thus, volumes of manufactured microwave radios have rapidly increased together with the fast growing cellular business. Within the increased volumes the traditional design methods [2] used for years inside the microwave society fail leading to too long assembly and testing times in the manufacturing.

In this work a novel microwave point-to-point radio platform has been developed for the frequency range of 13 – 38 GHz. The design of the radio was mainly driven by the requirements of the high volume manufacturing. A lot of effort was used in order to find an optimized architecture, mechanical structure, and chip level solutions, which all together dramatically improve the manufacturing process. According to the results of two years continuous high volume manufacturing, it is very obvious that the platform is very suitable for ultra high volumes.

II. SPECIFICATIONS

The new platform has frequency variants in the following standard ETSI bands: 13, 15, 18, 23, 26, and 38 GHz. As an example, the key performance parameters of the 13, 23, and 38 GHz radios are shown in Table 1. The radio utilizes π/4-DQPSK modulation within SW controllable symbol speed, which allows the same HW to be used with four different transmission capacities 2x2 Mbit/s, 4x2 Mbit/s, 8x2 Mbit/s, and 16x2 Mbit/s, and in four different channel bandwidths of 3.5 MHz, 7 MHz, 14 MHz, and 28 MHz, respectively.

TABLE I
KEY PERFORMANCE SPECIFICATIONS

	13 GHz	23 GHz	38 GHz
Maximum output power [dBm]	20	18	16
Minimum output power [dBm]	-6	-10	-10
Output power accuracy [dB]	± 2	± 3	± 3
RX noise figure [dB]	<6.5	<7.0	<8.0
Modulation	π/4-DQPSK		
Channel bandwidth [MHz]	3.5 - 28		
Capacity [Mbit/s]	2x2 - 16x2		

TABLE 2
KEY MANUFACTURING SPECIFICATIONS FOR OUTDOOR UNIT

Component type	SMD, except MMIC
Number of components per board	< 1500
Total testing time at board level	< 10 minutes
Assembly time of outdoor unit	< 5 minutes
Testing time for outdoor unit	< 15 minutes
Number of cables inside OU	None
Required microwave test equipment	Power meter
Tuning during manufacturing	Not needed

The key manufacturing specifications are shown in Table 2. In order to obtain the high volumes the assembly and testing times must be kept as short as possible. In order to obtain the fast assembly time the number of components must be low and they all must be SMD (Surface Mounted Device) components (expect the MMICs, which are all integrated to one separate microwave unit). Furthermore, no cables were allowed to be inside the outdoor unit.

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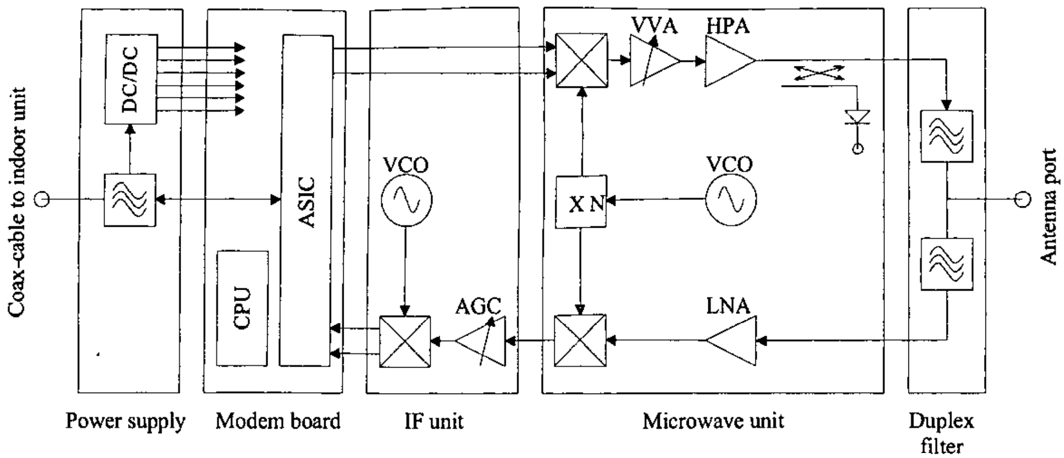

Figure 1. Block diagram of the outdoor unit.

III. OUTDOOR UNIT ARCHITECTURE

Figure 1 shows the top-level block diagram of the radio outdoor unit. The outdoor unit includes five functional units:

- Power supply unit (PSU),
- Modem board,
- Intermediate Frequency unit (IFU),
- Microwave unit (MWU),
- Duplex filter.

The outdoor unit is connected to the indoor unit by using a single coaxial cable, which carries the baseband data between the indoor and outdoor unit in full duplex mode. It also carries the required DC power to the outdoor unit. The cable is connected to the power supply unit in which the data traffic is filtered and transferred to the modem board. The required DC voltages are generated in the PSU and delivered to other units through the modem board.

Unlike the traditional outdoor unit designs, the modem board is located in the outdoor unit, which makes it possible to use more advanced control loops between modem board and RF parts (IFU and MWU). The main component of the modem board is the custom design ASIC. The ASIC contains a digital modulator and demodulator with Reed-Solomon forward error correction (FEC). The interface between modem board and RF portion is analog I and Q signals. The modem board includes also CPU with embedded SW, which is used to control all units inside the outdoor unit and also the far-end unit when needed.

The RF functions are divided between two units: IF unit and microwave unit. MWU includes all microwave circuits, most of which are MMICs, while IFU includes required intermediate frequency circuits.

In the transmitter side direct conversion architecture is implemented to enable use of a single microwave local oscillator. Since the I/Q up-converter operates at the end frequency, a digital feedback loop is required to correct the amplitude and phase errors of the modulator. After the up-conversion the signal is amplified enough in order to obtain the required maximum output power levels given in Table 1. A temperature compensated power detector is used to monitor the power level after the high power amplifier (HPA), and thus, to drive the voltage variable attenuator (VVA) in order to obtain the required output power level.

In the receiver side single IF conversion architecture is used. After the LNA the received signal is down-converted to IF. Automatic gain control (AGC) with an dynamic range of about 100 dB is used to obtain a constant rms-power level for the I/Q-demodulator.

The outdoor unit contains two separate phase locked oscillator circuits. In the MWU the fundamental oscillator frequency is multiplied in order to obtain the low phase noise LO signal for the transmitter (TX) and receiver (RX) up- and down-converters. Due to the common LO frequency at TX and RX, the IF frequency is always equal to the duplex spacing.

The waveguide duplex filter between the MWU and integrated antenna is used to separate the transmitter and receiver from each other and providing at the same time low loss connection to the antenna port.

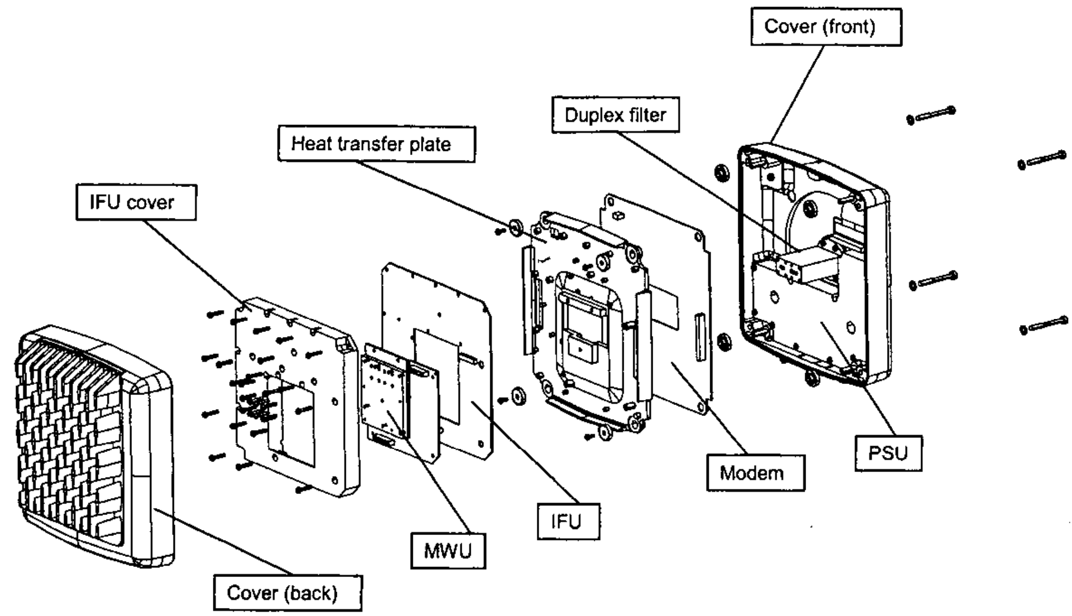

Figure 2. Mechanical construction of the outdoor unit.

IV. Mechanical construction

The mechanical construction of the outdoor unit is shown in Figure 2. The radio consists of four different boards: power supply board, modem board, IFU board, and MWU board. All boards are connected to each other by using standard pin-header connectors so that one board has a female connector and the other a male connector. Thus, no cables are required inside the outdoor unit, which significantly makes the assembly of the outdoor unit easier. Furthermore, the boards fit to each other easily with sandwich like structure, which is easy to assemble just by putting the next board over the previous one.

The mechanical structure includes six different kinds of custom designed, die-cast mechanical parts:

- Back cover,
- Local cover of MWU,
- Local cover of IFU,
- Heat transfer plate,
- Local cover of PSU,
- Front cover.

The MWU cover is used as local shield for the MMICs, which are located on a single substrate under the cover. The IFU cover is used to shield the IF circuits. A heat transfer plate is placed between the IFU/MWU and modem boards so that the heat transfer plate is in good contact with the base-plate of the MWU, and thus, transfers heat from the MMICs to the cover of the outdoor unit. Moreover, a PSU cover is used to shield other boards from the possible unwanted switching frequencies generated by the DC-DC power conversion on the PSU board. It should also be mentioned that there is totally only 42 screws inside the outdoor unit, which all are of the same type. The screws are located so that they can be tighten from one side of the assembly. Therefore, there is no need for rotating the assembly during manufacturing.

V. Manufacturing process

The entire manufacturing process of the outdoor unit can be divided into five sections:

- Assembly of boards,
- Testing of boards,
- Pre-assembly of mechanical parts,
- Assembly of entire outdoor unit,
- Testing of outdoor unit.

The PSU, modem, and IFU boards are all manufactured on standard SMD line. Detailed manufacturing data is shown in Table 3. The components used on these boards have harmonized SMD component package and type according to Nokia level regulations. On the other hand, all MMICs inside the MWU are placed on one single base-plate by using an automated assembly process. Each individual board is tested with automated testers designed specially for that board. The board level testing takes place only at room temperature and without any hardware tuning, which dramatically shortens the required testing time. This was achieved by careful design and verification of the needed margins over the required operating temperature range, and with the aid of internal digital control loops and sophisticated SW corrections.

The tested PSU, modem, IFU, and MWU boards are finally assembled together with the mechanical parts as shown in Figure 2. Due to the simple but effective sandwich structure, the total assembly time is less than 5 minutes. After that the complete outdoor unit is tested on unit tester, where also the calibrations are made. The unit testing takes less than 15 minutes all together. The outdoor unit is tested also only at room temperature without any need for hardware tuning, which saves dramatically testing time. After unit testing, a sample based audit testing is carried out over temperature. The purpose of the audit testing is to assure that changing in component parameters, do not affect radio performance over temperature.

Compared to the traditional designs, two key factors for improved manufacturing process are the easy and fast assembly of the entire outdoor unit, and the fast testing times without the need for testing over temperatures. The latter thing is possible due to the fact that the modem is located inside the outdoor unit, which makes it possible to use advanced digital control and correction loops between modem board and RF parts. Furthermore, the process variations were analyzed very carefully during design phase in order to meet the target of no HW tuning is allowed during the manufacturing process. Within the untuned design the electronics of the outdoor unit will stand less possible stress during manufacturing because there is no need to change or tune the components. And, thus the reliability increases.

TABLE 3
MANUFACTURING DATA OF OUTDOOR UNIT

	IFU	Modem	PSU	OU
Number of components	275	1230	444	-
Assembly time [s]	<150	<210	<90	<300
Testing time [s]	<160	<200	<140	<900

VI. Conclusion

A highly integrated microwave point-to-point outdoor unit platform has been developed, tested, and ramped up in production for the frequency bands of 13-38 GHz. The tight design requirements set by the manufacturing process for high volumes were met successfully. The key factors for this success were the highly integrated electro-mechanical structure, untuned design, and fast, effective testing. Thus, after two years of full scale manufacturing we could conclude that the platform is suitable for ultra high volumes.

References

[1] P. Mikkonen, "Modern 60 GHz radio link," *Proceedings of the 29nd European Microwave Conference*, Munich, Germany, 1999.

[2] G. Marzocchi (edit), "The emergence of new microwave systems above 45 GHz," *MTT-S International Microwave Symposium workshop WFFR*, Anaheim, CA, 1999.