Demonstration of Low-Cost UHF Transceiver

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Purpose and Functions

Purpose:

To develop the new Transceiver are to achieve the same performance, data rate and low power consumption at a lower cost than the commercial UHF TRX.

Functions: (Same as commercial UHF TRX)

- Receive uplink command from the ground station (GS), and send the received command to the onboard computer (OBC)
- Transmit mission or payload data via downlink to the GS
- Transmit continuous wave (CW) beacon to the GS

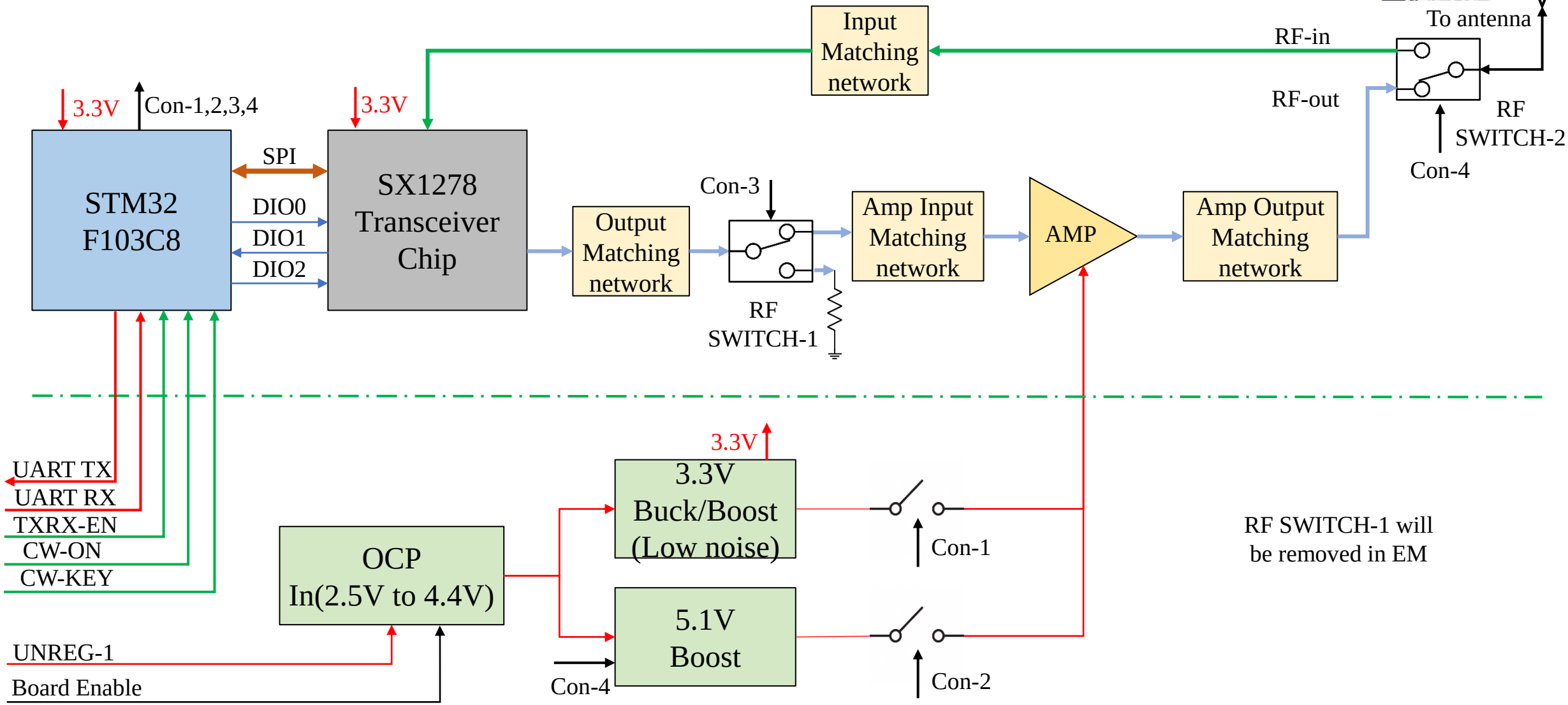
Design Parameters

- **Telemetry and mission data downlink**
  - Frequency – 437.375 MHz
  - Bandwidth – 12 kHz
  - Modulation – GMSK
  - Output power – 29dBm
  - Data Rate – 4800 bps
  - AX25 (G3RUH)

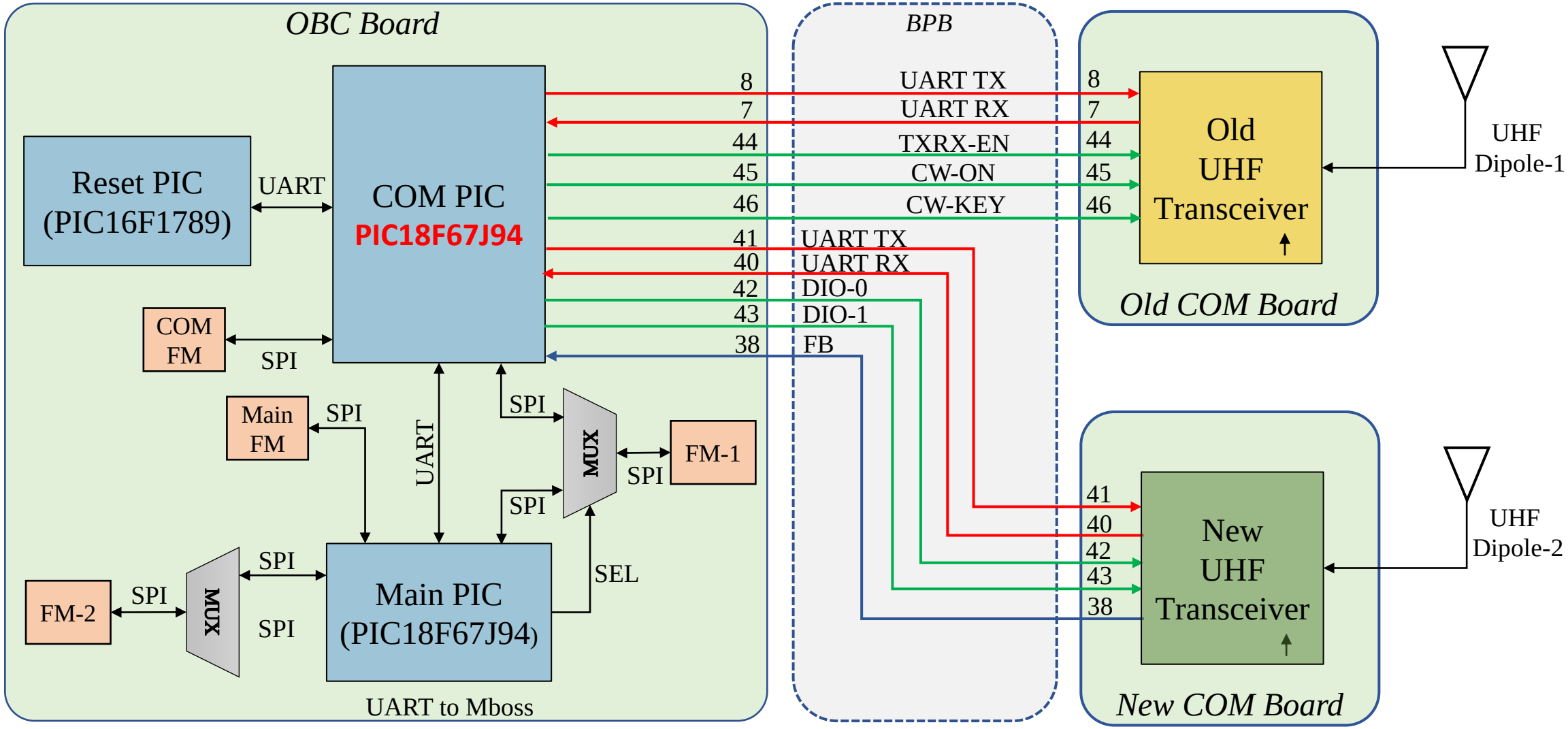
- **Command Uplink**
  - Frequency – 435.313 MHz
  - Bandwidth – 12 kHz
  - Modulation – GMSK
  - Data Rate – 4800 bps
  - AX25 (G3RUH)
  - Sensitivity > -96 dBm

- **CW Beacon**
  - Frequency – 437.375 MHz
  - Band Width – 500 Hz
  - Modulation – CW Morse code
  - Output power – 20dBm
  - Data Rate – 20 wpm

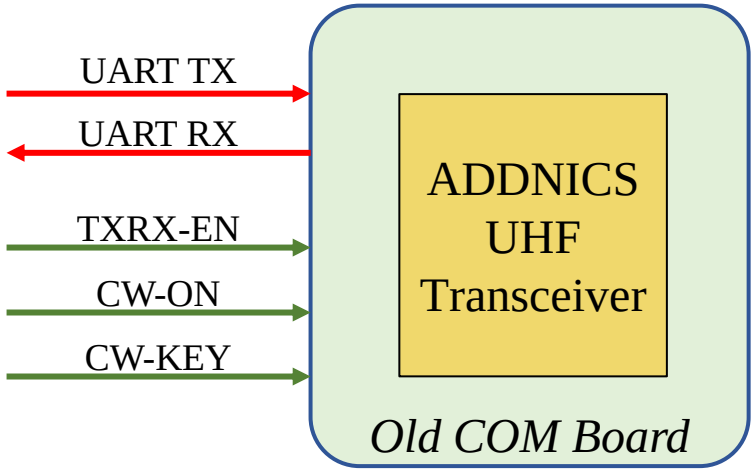
New UHF Transceiver Block Diagram

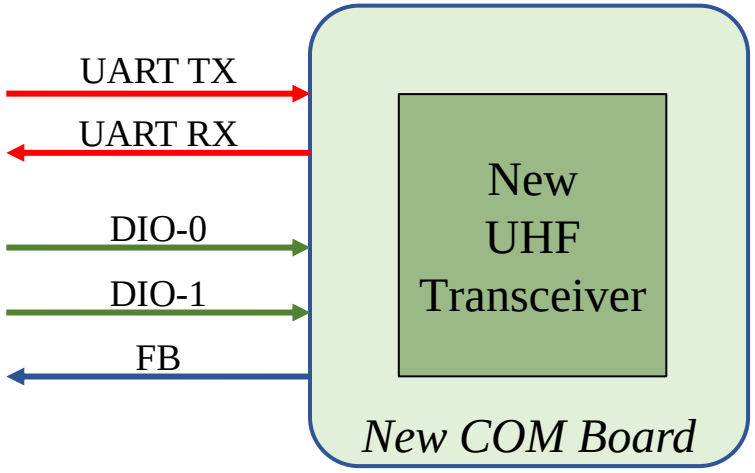


New Transceiver Integration with COMPIC



Enabling Different Modes





	TXRX-EN	CW-ON	CW-KEY
Transmitter Mode	1	0	Not used
Receiver Mode	0	0	Not used
CW Mode	0	1	CW Key

	DIO-0	DIO-1	FB
Transmitter Mode	1	0	Feed back
Receiver Mode	0	0	Not used
CW Mode	0	1	Not used

Transceivers Comparison

	ADDNICS Transceiver	New UHF Transceiver
UART Communication	115,200 bps	115,200 bps
DIO Pins	Two DIO pins to change Modes (TXRX-EN, CW ON)	Two DIO pins to change Modes (DIO-0, DIO-1)
Method of CW transmission	COMPIC has to do the CW keying (About 30 seconds COMPIC is busy)	CW keying is taken care by new transceiver. COMPIC just has to transfer CW data using UART. (takes only about 1 second)
Uplink command	14-bytes and 38 bytes packet type	Uplink command can have any number of byte less than 150 bytes.
Standby Mode	No standby Mode	Yes. There is a standby mode
Different Modulation	Only GFSK and Morse beacon	GFSK, LoRa, OOK, Morse beacon
Transmission complete Feed back pin	No	Yes, Implemented

Transceivers Comparison

	ADDNICS Transceiver	New UHF Transceiver
Properties changing (Frequency, data rate, etc..)	ADDNICS company has to do.	Can be changed easily

About Feed Back PIN

- With 4800bps , ADDNICS transceiver takes about 175ms to transmit 105 byte long packet.

$$time = \frac{105 \times 8}{4800} = 175\ ms$$

- The COMPIC transfers the packet to the ADDNICS transceiver with a 200ms delay. Subsequently, the transceiver transmits the packet. This particular method is employed by all the BIRDS satellites.

- However, there is an issue with this method. In the G3RUH encoding, if the packet contains the bytes 0xC0 and 0xDB, they will be replaced with 0xDB, 0xDC and 0xDB, 0xDD, respectively.

- If the packet contains more occurrences of 0xC0s and 0xDBs, the transmission time of the packet may exceed the 200ms delay. As a result, if we continue using above mentioned method, the COMPIC will transfer the next packet while the transmitter is still transmitting the previous packet. Consequently, the current packet will be lost in this scenario.

- To address this issue, the new transceiver has a feedback mechanism using a digital pin. When the transmission of a packet is completed, this pin transitions to a low state, signalling that the transceiver is ready for the next packet. This enables the COMPIC to transfer the subsequent packet to the transceiver without the risk of losing it.

GMSK transmission

To generate GMSK signal, 2-FSK modulation in SX1278 transceiver is used

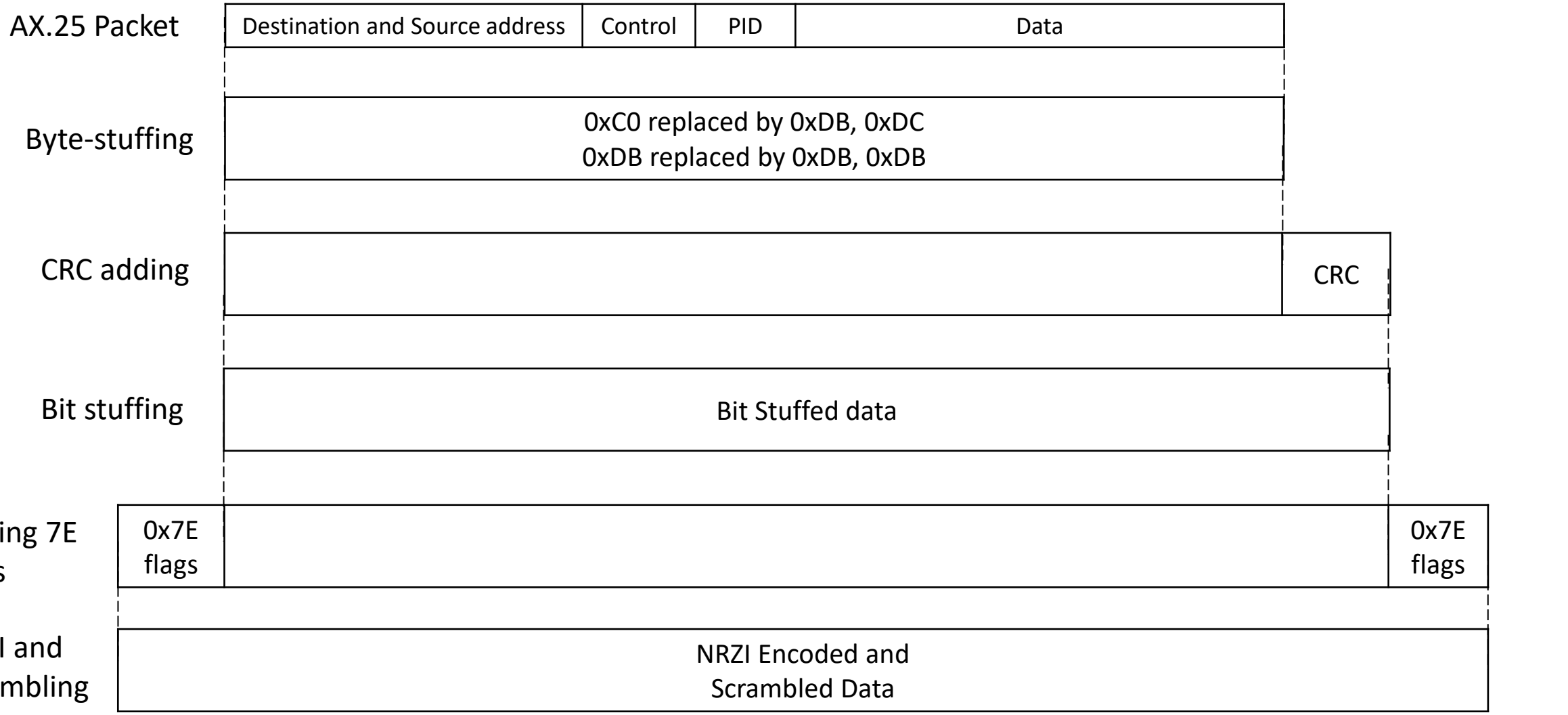
1. First we have to set the frequency deviation of FSK modulation to 1.2kHz to convert FSK to MSK (Modulation index 0.5 gives the MSK modulation).

$$Modulation\ index = 2 \times \frac{frequencydeviation}{Data\ rate} = 2 \times \frac{1.2}{4.8} = 0.5$$

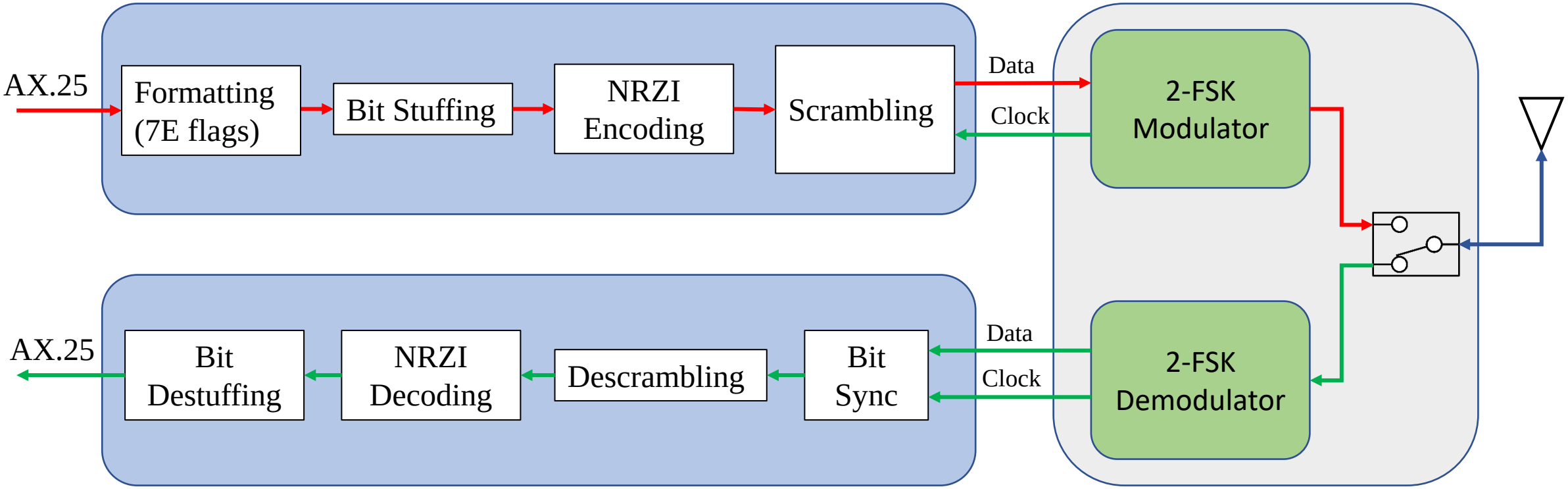
2. Before the MSK modulation data bits are filtered using a gaussian filter to get GMSK signal output

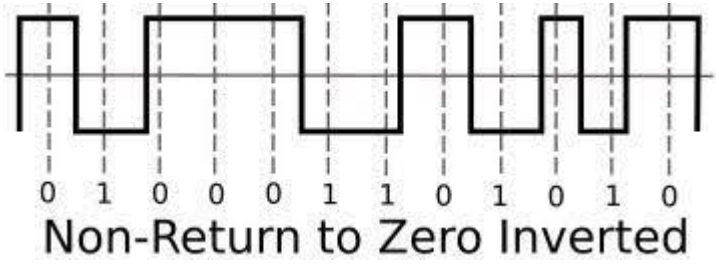
3. This data bits are G3RUH encoded

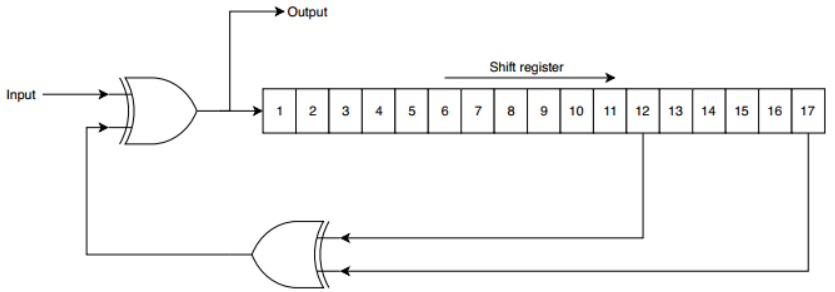
G3RUH Encoding and AX.25

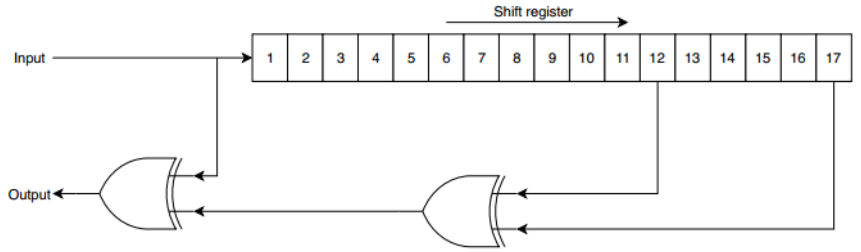


Transceiver MCU packet processing

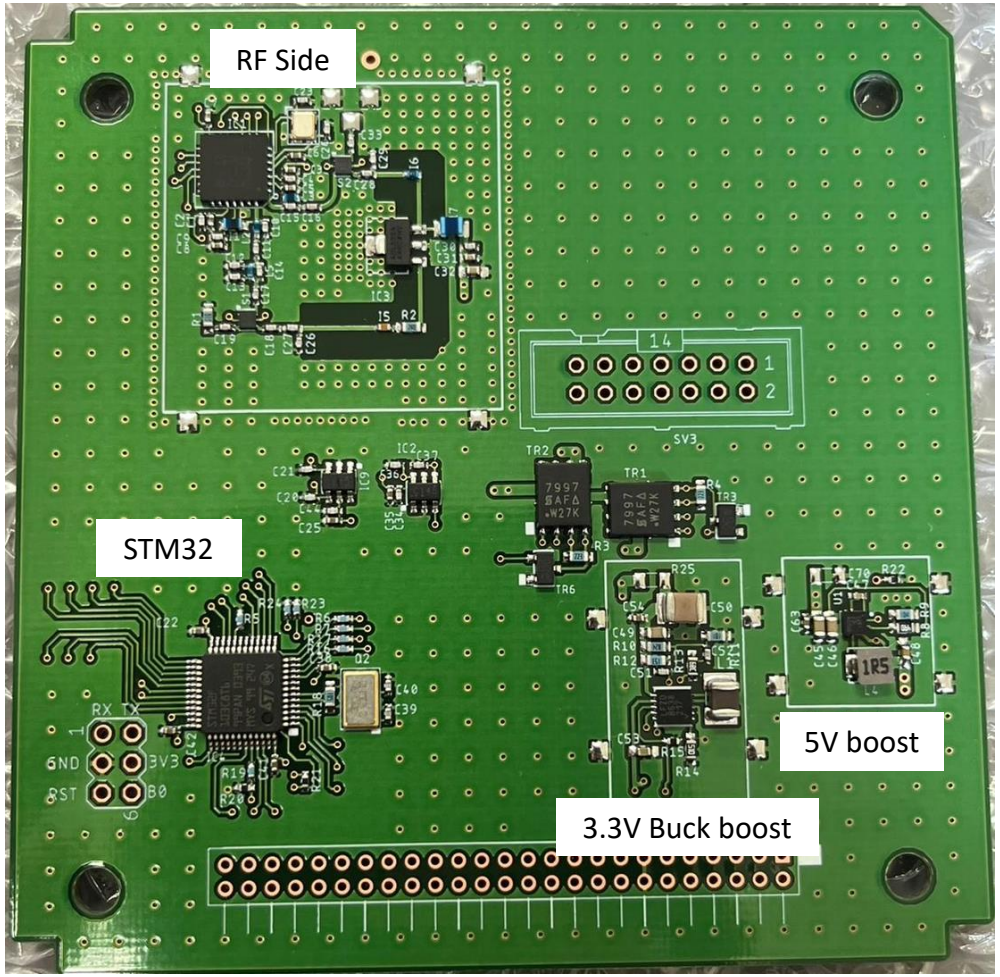


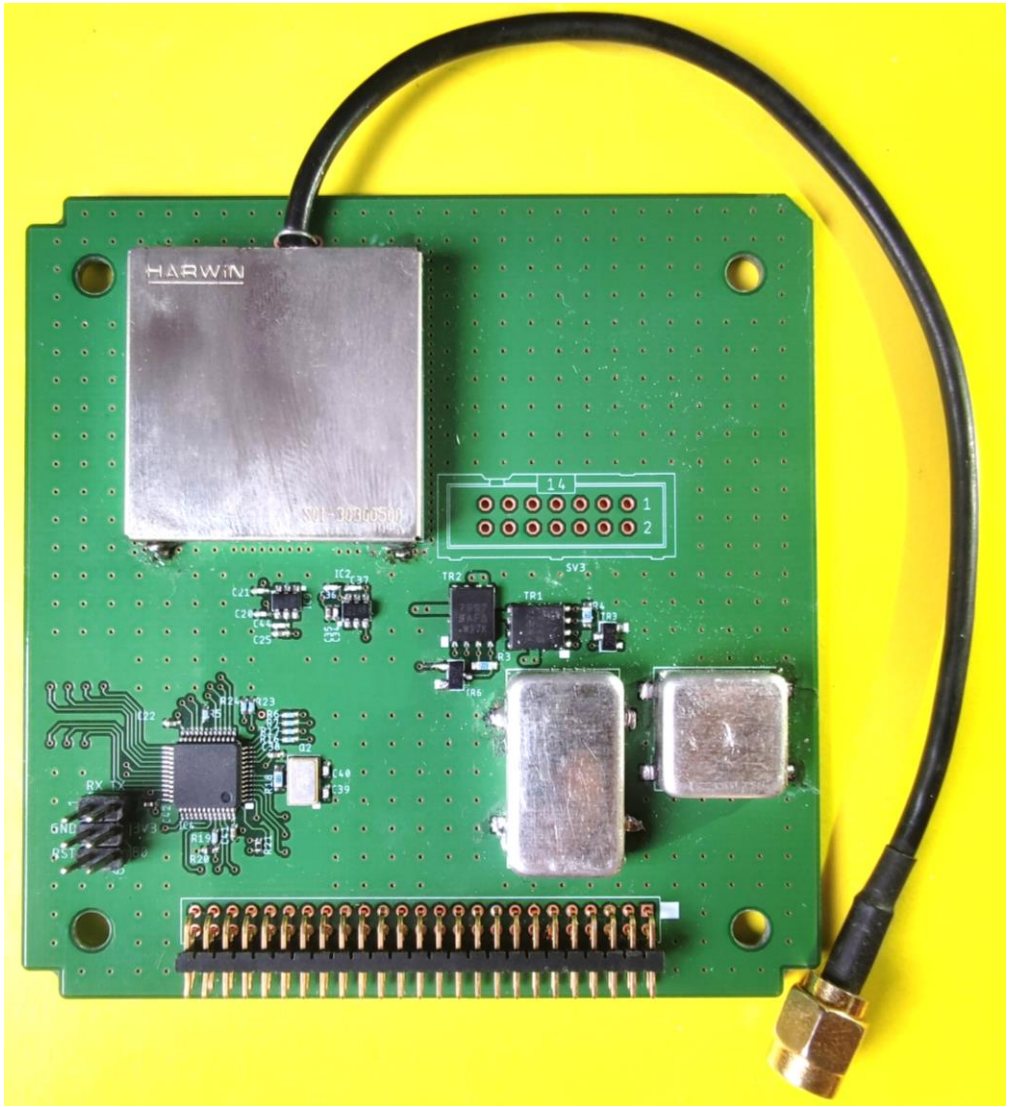




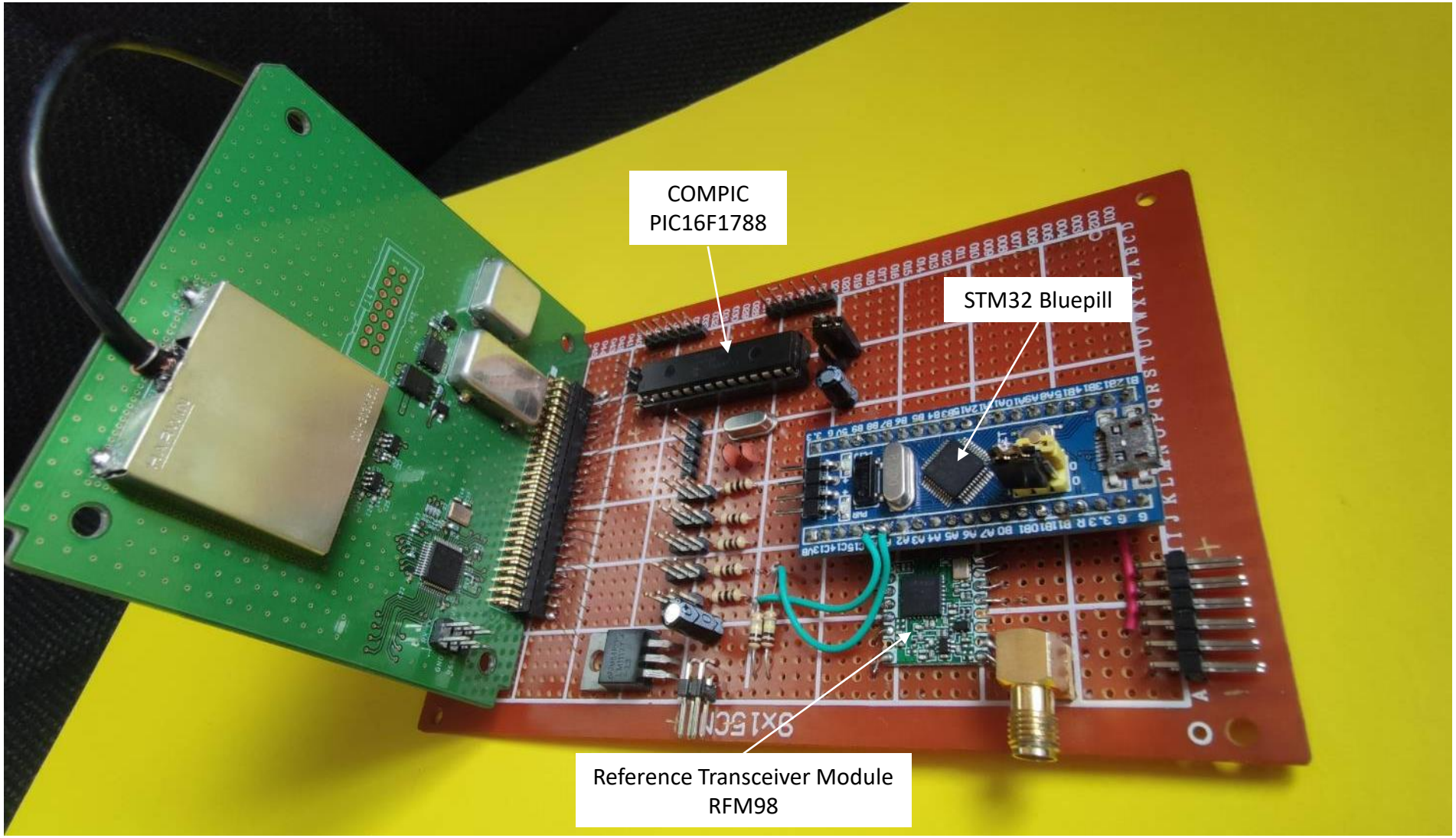


BBM Board





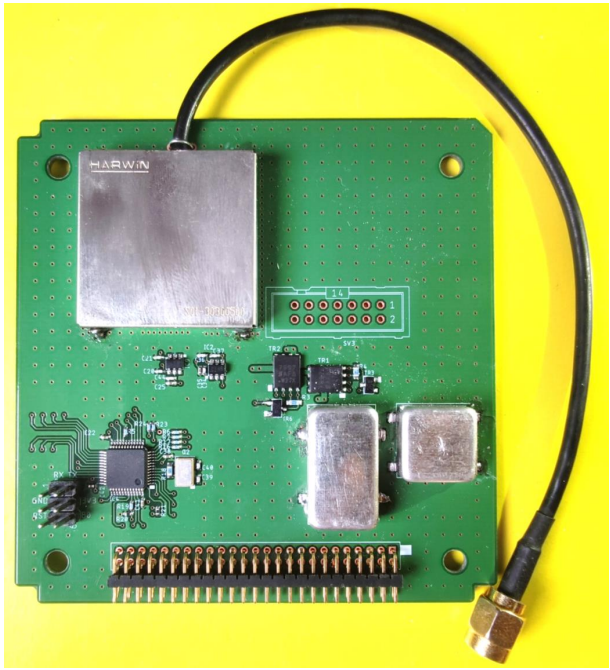
BBM Testbed


COMPIC
PIC16F1788
STM32 Bluepill
Reference Transceiver Module
RFM98

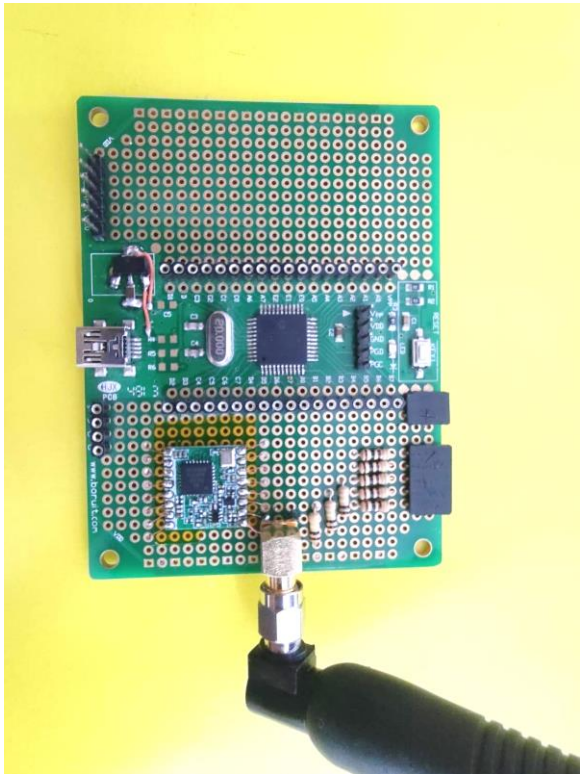
Different BBM Boards

ATMEGA32U4
3.3V, 16MHz

ATMEGA2560
5V, 16MHz



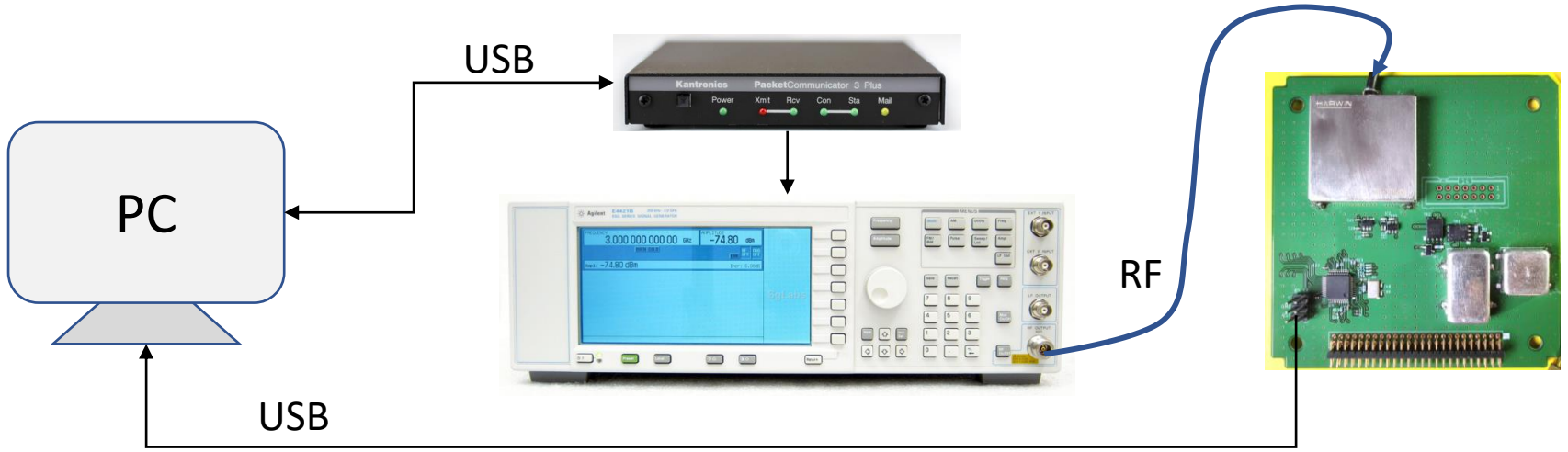
STM32F103C8
3.3V, 72MHz



PIC18F46J11
3.3V, 20MHz

New Transceiver Receiver Sensitivity

Test Setup



	ADDNICS Transceiver	New UHF Transceiver
Measured Sensitivity (Cable test)	-114 dBm	-118 dBm
Datasheet Value	-	-120 dBm

Power Consumption

Transmit Mode [GMSK, Output Power = 630mW (28dBm)]				
	Voltage	Current	Power	Efficiency
ADDNICS TRX	3.8 V	1100 mA	4180 mW	19 %
New TRX	3.3 V	600 mA	1980 mW	32 %

Receive Mode (GMSK)				
	Voltage	Current	Power	Efficiency
ADDNICS TRX	3.8 V	116 mA	440 mW	23 %
New TRX	3.3 V	110 mA	363 mW	28 %

CW Mode [Output Power = 100mW (20dBm)]			
	Voltage	Current	Power
ADDNICS TRX	3.8 V	42 mA	160 mW
New TRX	3.3 V	40 mA	132 mW

Board Manufacturing Cost

- Components cost for three boards = 50,000 yen
- Three board manufacturing and soldering cost = 110,000 yen
- Total cost per board = 54,000 yen

Performance Summary

	Sub System	Status	Performance
1	GMSK AX.25 G3RUH Encoded packet reception	Transceiver can successfully decode the GS command	-118 dBm cable test sensitivity
2	GMSK AX.25 G3RUH Encoded packet transmission	GS can decode the received packet from the transceiver	630mW (28dBm) power output
3	CW morse beacon transmission	CW beacon sent by the transceiver was decoded correctly	100mW (20dBm) power output
4	Electrical power system of the transceiver	Bothe 3.3V buck-boost and 5V boost convertor are working in nominal condition	3.3V buck-boost output = 3.304V 5V boost output = 5.05V (No measurable noise in UHF)

Thank You