Telemetry beacon for Polish payload on BRITE-PL-2 satellite

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ABSTRACT

Small satellite missions are becoming more popular. To reduce costs of such projects COTS are used to build the spacecraft and amateur bands are utilized to communicate with it. Although using the hamradio frequencies is free of charge and requires only coordination procedures [1], it is good habit to include on satellite some service for radioamateur society in return. The BRITE-PL-2 Heweliusz [2] satellite – the second Polish satellite from BRITE constellation – will have an S-Band beacon transmitting Morse code signals.

Keywords: satellite, BRITE-PL, Heweliusz, beacon, transmitter, s-band, hamradio, amateur radio

1. INTRODUCTION

BRITE-PL satellites are part of BRITE constellation planned by international consortium gathering scientific and engineering institutions from Austria, Canada and Poland. By the time of writing this article two Austrian BRITE satellites (TUGsat and uniBRITE) are already in the last phase of commissioning procedure in the orbit. First Polish satellite BRITE-PL-1 Lem is integrated and tested and BRITE-PL-2 Heweliusz is being integrated.

The second Polish satellite Heweliusz contains experimental payload of various experiments. One of them is CW telemetry beacon working on amateur s-band frequency. Since such rather high frequency pose some problems with narrowband modulation like CW this article describes solutions used and results obtained during designing and building of this device.

2. DESIGN OF BEACON HARDWARE

Beacon device is supposed to transmit CW Morse Code on S-band frequency. Since this is connection of narrowband modulation with high carrier frequency, good frequency stabilization is required. This is achieved with few constructional solutions. Below the block diagram of the device is presented [Fig.1].

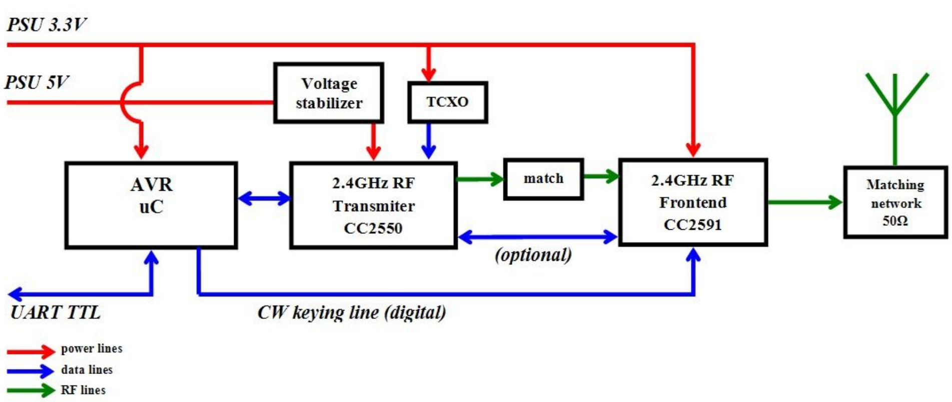

Figure 1. Block diagram of beacon structure

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The transmitter used is CC2550 digital transmitter [3] which is followed by CC2591 amplifier [4] giving in result 20dBm output power. To avoid signal carrier deviation while keying transmitter, the amplifier is keyed instead while CC2550 transmitter is acting as carrier generator. Morse code keying signal is generated by ATmega128 microcontroller. The transmitter is powered with separate voltage line through voltage stabilizer to obtain smooth 3.3V supply uninfluenced by power drain caused by instantaneous keying of the CC2591 amplifier. Finally, the clock signal for transmitter is generated with use of stable TCXO since target environment – satellite on Earth's orbit – has dynamic temperature changes.

The Atmega128 is using UART interface to communicate with PSU (power supply unit) unit which is used also as the main managing computer for the whole Polish payload. The interface is used to pass data to be transmitted by beacon. Beacon is returning information about status of the transmission and information about temperature of transmitter. The temperature information can be used to correct the frequency readout while performing Doppler positioning of the satellite.

3. MEASUREMENTS OF BEACON PERFORMANCE

In space applications it is required that all the devices: electronic as well as mechanical ones should be resistant to harsh environmental conditions that are present in the orbit or in outer space.

Beacon has been tested under thermal shock test which relies on fast temperature cycling creating high gradients of temperature change in order to check assembly and soldering quality. These are also conditions that may occur during satellite launch and in orbit. This is so called t-shock test.

The second test was checking RF parameters (carrier frequency and output power level) of the device under different temperatures in vacuum chamber. This is so called t-vac test. The result of these tests is shown on the plots below [Fig.2].

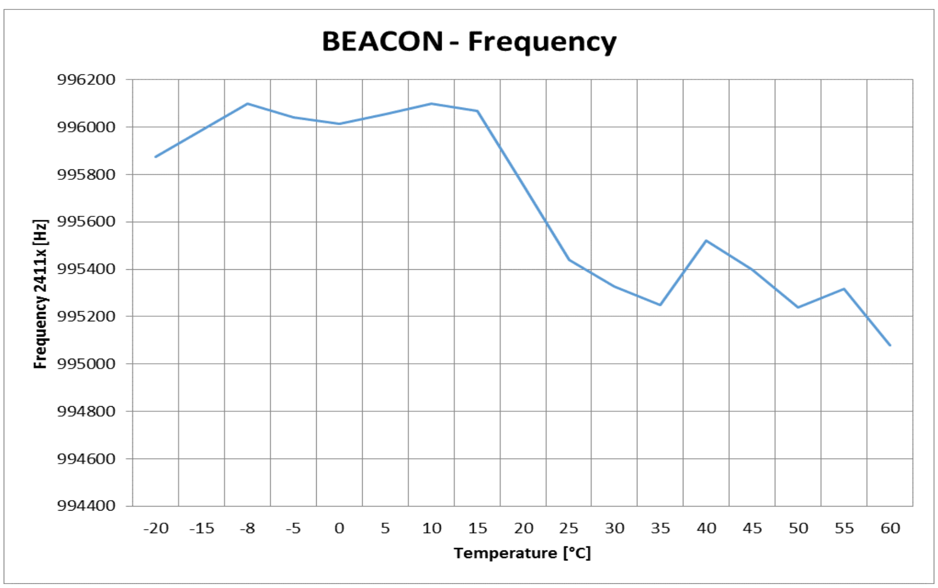

Figure 2. Frequency vs temperature

The frequency drift dependent on changing temperature is small due to used constructional solutions described above. The total drift in the temperature range from -20 to +60 ºC is about 1kHz which means …ppm. This is very good result for CW transmission taking into account that temperature change during regular orbit operation is slow and not so wide as tested.

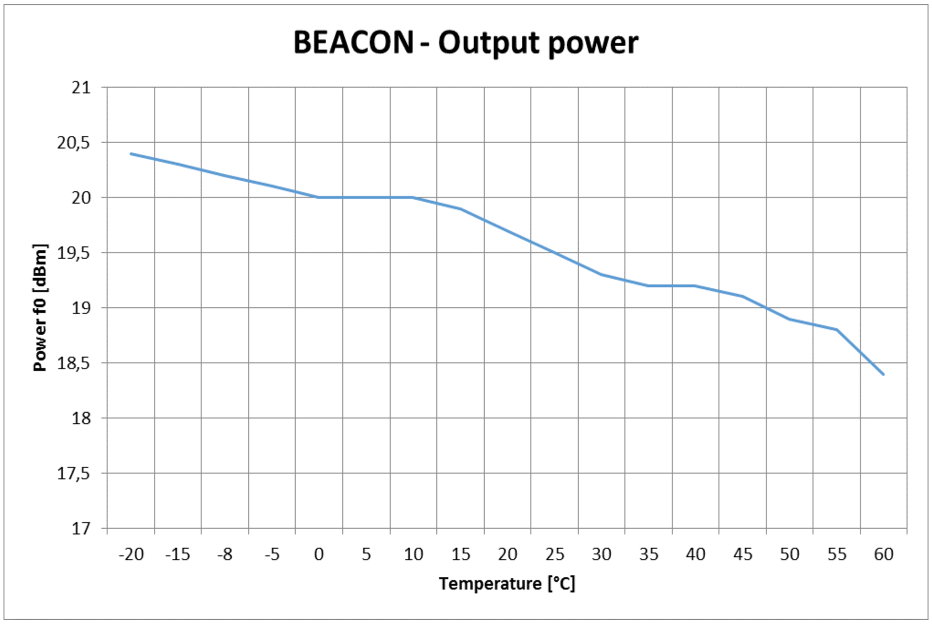

Figure 3. Output RF power vs temperature

The second plot [Fig.3] presents the result of output power measurement and how it changes respect to the temperature. The total power change is 2dB across the temperature range from -20 to +60 ºC which is acceptable.

Spectral measurements were also performed to justify the signal shape.

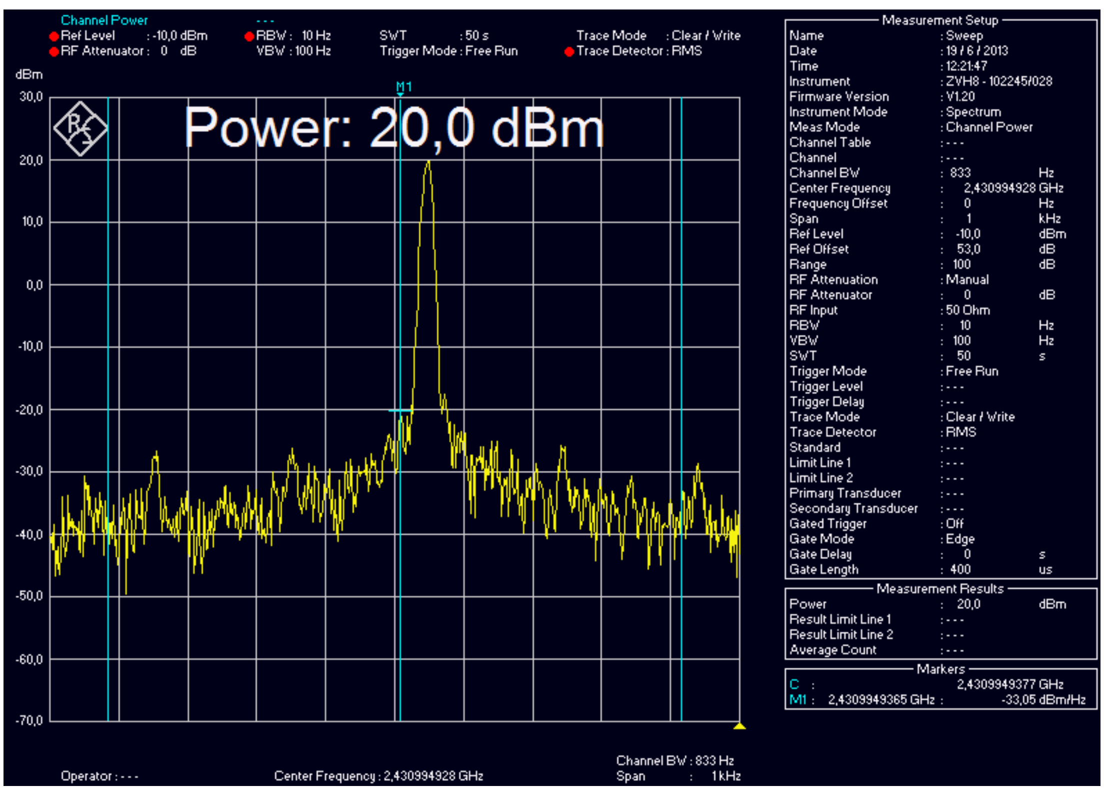

Figure 4. Spectral measurement of the beacon signal

The picture of the signal width is presented above [Fig.4]. It can be seen that the signal width is not exceeding 50Hz.

4. LINK BUDGET CALCULATIONS

Based on the parameters of the actual ground station for BRITE satellites placed in N. Copernicus Astronomical Centre the link budget for the beacon signal can be calculated. The results are shown in table below.

Table 1. Link budget calculations

	Inputs	Calculations	Unit
Frequency	2400		MHz
Wavelength	0,1249		m
Transmit power (mWatts)	100,00	20,00	dBm
Feed harness loss	1,5	-1,50	dB
Antenna Mismatch Loss (VSWR)	2	-0,51	dB
Antenna gain		0,00	dBil
EIRP		**17,99**	**dBm**
Satellite orbital altitude (circular orbit)	900		km
Minimum elevation	5		degrees
Maximum distance to satellite	2993,71		km
Free space loss		-169,58	dB
Polarization mismatch loss	3		dB
Atmospheric loss	1		dB
Total propagation loss		-173,58	dB
Isotropic signal power at Antenna Input		**-155,59**	**dBm**
Antenna size	3,00		m
Antenna efficiency	70,00		%
Antenna gain		36,00	dBic
Antenna beamwidth (half power)		2,91	degrees
Pointing error	0,5		degrees
Pointing loss		-0,35	dB
Feed Harness loss	0,5	-0,50	dB
Preamplifier Noise Figure	0		dB
Preamplifier Gain	0		dB
Cable Loss	3		dB
Receiver Noise Figure	4,5		dB
System Noise temp (K)	1692,87	32,29	dBK
G/T		**3,36**	**dB/K**
Receiver Signal Power	**-119,94**		**dBm**
Receiver Noise Power	**-143,30**		**dBm**
C/No		46,38	dB
Receive Bandwidth	200	23,01	dBHz
C/N		23,37	
Implementational Losses	1	1,00	dB
Baseband S/N		**22,37**	**dB**
Required S/N for CW	0	0,00	dB
Downlink Margin		**22,37**	**dB**

The margin of received signal is still enough to receive the beacon signal with much smaller antennas than that mounted in the ground station (which has 3m diameter). This makes it possible to radioamateurs which are equipped with proper tracking systems and directional antennas [5].

5. TRANSMISSION SCHEME AND DECODING

The beacon device will be transmitting static text followed by the data received from other payload subsystems by the means of PSU. The scheme is as presented in [Table.2]:

Table 2. Beacon text scheme

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hihi,brite-pl2,heweliusz,www.brite-pl.pl,t=+00,hihi,[payload data
max.256b],hihi,end[60sec. idle carrier]
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The transmission speed is about 50LPM (letters per minute) or 10 WPM (words per minute). The speed of transmission is measured by transmission of the reference word “PARIS”. Word is standardized as 5 letters. Due to low speed the transmission can be decoded manually by hearing or computer software can be applied. The authors were using CWGet software to decode transmission. The sample of decoding process is presented in [Fig.5].

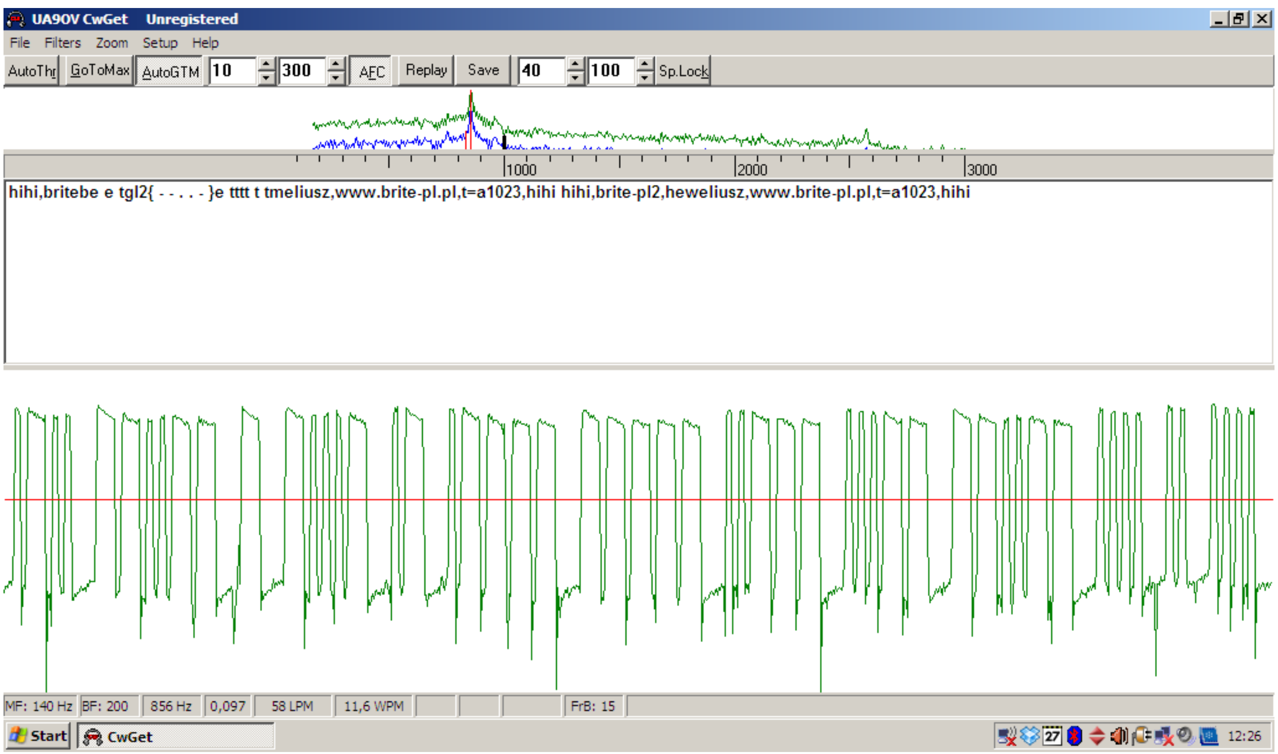

Figure 4. Spectral measurement of the beacon signal

6. SUMMARY

The article presented constructional solutions and measurements of the telemetry beacon mounted on the BRITE-PL-2 Heweliusz satellite. The simulation of the budget link gives positive result so the beacon signal can be received with success. The beacon signal, besides transmitting of secondary scientific payload telemetry can be used for Doppler positioning of the satellite [6] by measuring the frequency of the carrier signal during the pass over ground station. This is useful technique especially during malfunction of the primary communication link.

The another benefit of beacon device is delivery of microwave satellite transmitter to radioamateur community. Microwave amateur bands above 1Ghz are still not so popular as VHF and UHF so this is next step in making bigger interest of them. Moreover radioamateurs can deliver many useful information about the received telemetry and quality of the signal.

REFERENCES

[1] AMSAT frequency coordination, http://www.amsatuk.me.uk/iaru/
[2] Orleański P., Graczyk R., Rataj M., Schwarzenberg-Czerny A., Zawistowski T., Zee R.E., "BRITE-PL: the first Polish scientific satellite", Proceedings of SPIE, Vol. 7745, pp. 77450A1-A8 (2010)
[3] CC2550 Single-Chip Low Cost Low Power RF-Transmitter (Rev. B) , http://www.ti.com/product/cc2550
[4] CC2591 2.4 GHz RF Front End (Rev. A), http://www.ti.com/product/cc2591
[5] Woźniak G., Stolarski M., "Low cost amateur rotators for student's satellites and high altitude balloon application", Proc. SPIE 8454, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2012, 84540F (October 15, 2012); doi: 10.1117/12.2000189
[6] Stolarski M., Woźniak G., "Estimation of PW-Sat satellite orbit based on Doppler effect", Proc. SPIE 8454, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2012, 84540H (October 15, 2012); doi: 10.1117/12.2000192