Resonant Radar Reflector On VHF / UHF Band Based on BPSK Modulation at LEO Orbit by MRC-100 Satellite

Yasir Ahmed Idris Humad, and Levente Dudás

Abstract—**This paper presents a novel method for identifying and tracking PocketQube satellites: the MRC-100 satellite is a model, and this method is based on a resonant radar reflector. The resonant reflector's basic concept is that the resonant reflector uses a VHF/UHF communication subsystem antenna; there is no radiated RF signal, which means the power consumption is only some Milliampere (mA). The continuous wave (CW) illuminator RF source is on the ground, and the onboard antenna receives the CW RF signal from the Earth. The microcontroller (uC) periodically switches PIN diode forming BPSK modulated signal reflection so that another Earth station can receive the backscattered Binary Phase Shift Keying (BPSK) modulated signal. Also, it can detect the satellite if the ground station receiver can use a matched filter like a correlation receiver. If the ground station receiver knows the BPSK code of the satellite, it can detect it. If not, there is no way to detect the satellite. This method is similar to Radio Frequency Identification (RFID) applications, but the reader is the ground station, and the tag is the satellite.**

Index Terms—**PocketQube, Student Satellite, Resonant Radar Reflector, Ground Station**

I. INTRODUCTION

MOST launches in the past involved a single large satellite being launched on a specialized launch vehicle. Small satellites were sometimes ' dropped off ' on the route to the primary payload's orbit or rode along with the primary payload to the final orbit. In either case, identifying primary and secondary payloads based on size and operational parameters was usually clear. By launching CubeSats close together in space, they are difficult to differentiate from one another; by launching them close together in time, Sorting out which object is which can take weeks or months at times, and some objects may never be individually identified at all. After launch, it is difficult to identify the satellite if there is no radio connection between the satellite and the ground station [1], [3], [4], [14].

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This paper's primary goal is to present a novel method for tracking and identifying PocketQuebe satellites without needing a costly tracking system. This method considers the satellites' weight, size, and power consumption while maintaining compatibility with the technology readiness level (TRL) and the global standardization of the PocketQube satellite's standard. The most recent satellite mission from BME University is the MRC-100 satellite, which is shown in the following sections to demonstrate the ability to identify and track the PocketQube satellites based on the resonant radar reflector described.

Little research has been done on the topic; the most closely related work in this field finds the French radar surveillance system's reflected signal (GRAVES). The radar-based space surveillance system Graves emits continuous waves at 143,05 MHz on the VHF band [15]. In this article, the authors could detect many hundred-kilogram satellites in low Earth orbit. PocketQube satellite has a much smaller radar-cross section (RCS) compared with hundred-kilogram satellites, so although it seems possible, research has to be done to determine the feasibility of small targets.

The PocketQube Satellite is the most recent type of nano-satellite to be proposed. It limits developers to a volume of roughly (5 $\times$ 5 $\times$ 5) cm for one unit and a mass range of 0.1 to 1 kilogram. The Microwave Remote Sensing Laboratory at BME University, in the Department of Broadband Info-communications and Electromagnetic Theory, developed various PocketQube Satellites experiments. MRC-100 is the new PocketQube Satellite and was developed over three years through the collaboration of lecturers, researchers, and students. It was given that name in honor of the Muegyetemi Radio Club (MRC), which will celebrate its 100^{th} anniversary in 2024 [16]. All small satellites were developed with significant help from the club [2], [6], [11].

MRC-100 is a 3-PQ (PocketQube) satellite with (50 $\times$ 50 $\times$ 178) mm dimension and 587 grams total mass. The main subsystems of MRC-100 are COM - Communication System, OBC - On-Board Computer, and EPS - Electrical Power System. MRC-100 contains several scientific payloads: **Resonant Radar Reflector**, spectrum analyzer 30 - 2600 MHz, 1 Mbit/s S-band down-link, automatic identification system receiver for vessel traffic services, memory-based single

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event detector, special thermal insulator test, UHF-band LoRa-GPS Tracking, total ionizing dose measurement system, active magnetic attitude control, horizon + Sun camera, and satellite GPS + LoRa downlink (satellite identification) [1], [3], [4]. The three dimension model and the cross-sectional view of MRC-100 subsystems can be seen in Fig. 1. and Fig. 2.

The article is structured as follows: Section I overviews the introduction of the PocketQube satellite and the base sub-systems of the MRC-100 satellite. Section II discusses the power budget estimation and the orbital motion estimation of MRC-100 satellite. Section III discusses the MRC-100 communication system and ground stations. Section IV discusses the concept of the proposed resonant radar reflector based on BPSK modulation. Section V discusses the link budget estimation of the proposed System. Section VI shows the preliminary idea of the reflector and laboratory measurements results. Finally, the article's conclusion and prospects for the MRC-100 satellite are presented in Section VII.

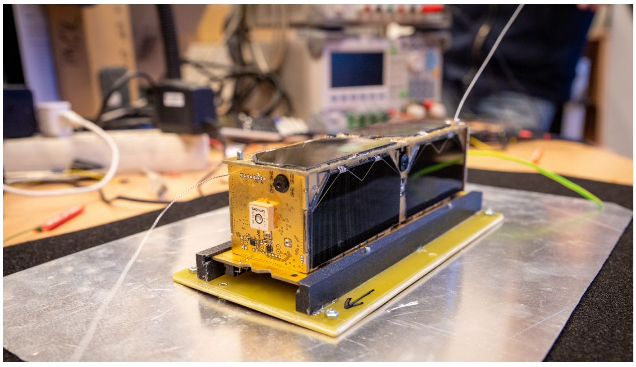

Fig. 1: MRC-100 flight module

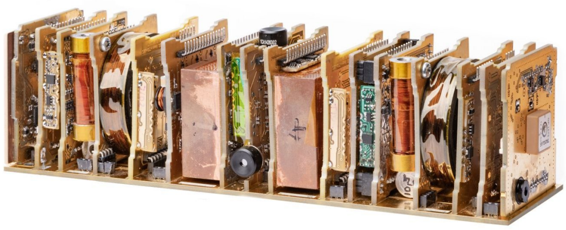

Fig. 2: Cross-sectional view of MRC-100 subsystems.

II. Power Budget and Orbital Motion Estimation of MRC-100

The MRC-100 satellite trajectory is scheduled to follow a polar, circular, and sun-synchronous Low Earth Orbit (LEO) with 600-kilometer apogee and perigee distances.

A. Power budget estimation

About 150 million kilometers is the distance between the Sun and the Earth. $1360\frac{W}{m^2}$ is the average power density around the Earth. As shown in Fig. 3. MRC-100 is covered with eight (80×40) mm three-layer solar panels from AzurSpace [7].

Due to the atmosphere, the solar power density on Earth's surface is only $1000\ \frac{W}{m^2}$ (mainly by the ozone layer). The MRC-100's three-layer solar cells have a $40\ mm \times 80\ mm$ size, a 28% efficiency, and 1.1 W of DC (Direct Current) output. The LEO of MRC-100 lasts 90 minutes, spending 60% of that time in light and 40% in darkness. As a result, the DC input averages 0.68 W with a peak of 1.7 W (on LEO, the DC input will be 36% higher) [3], [5], [12], [13]. The onboard systems of the MRC-100 is a single-point-failure tolerant and cold-redundant.

The three-layer solar cell dimension (80×40) mm and the cut-off edge of the solar cell (13.5×13.5) mm for a 1U cube (100×100) mm are both important factors in estimating the peak power of $1.7\ W$.

$$\frac{[(80 \times 40) - (13.5 \times 13.5)] \cdot 2}{(100 \times 100)} = 60\% \tag{1}$$

The solar power density around the Earth's surface equals $1000\frac{W}{m^2}$ (for $10\ cm^2$ cube equal to $10\frac{W}{cm^2}$). In equations (2) - (5) the estimation of overall DC power, the maximum DC input, the mean DC power, and the mean DC input in one orbital period (90 minutes) [3].

$$\text{Overall DC power } = 10\ W \cdot\ 60\% = 6 \text{ W} \tag{2}$$

$$\text{Maximum DC input } = 6\ W \cdot\ 28.5\% = 1.71 \text{ W} \tag{3}$$

$$\text{Mean DC power } = 1.71\ W \left(\frac{4\ sides}{6\ sides}\right) = 1.14\ W \tag{4}$$

$$\text{Mean DC input } = 1.14\ W \cdot\ 60\% = 0.684\ W \tag{5}$$

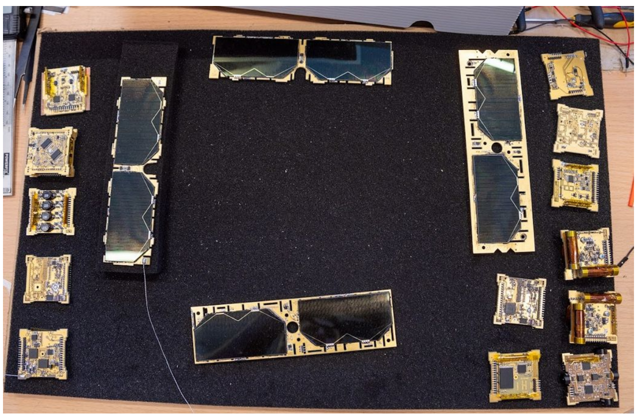

Fig. 3: MRC-100's solar cells

B. The estimation of orbital motion

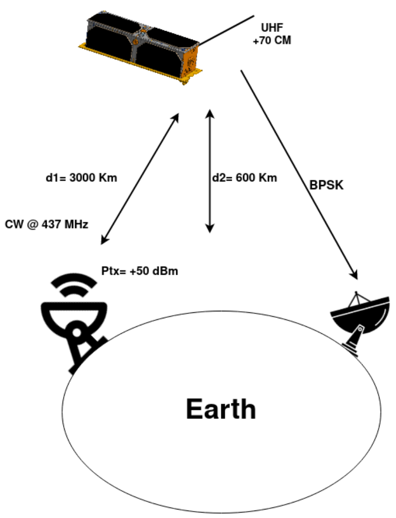

Fig. 4: Graphical depiction of the satellite horizon.

MRC-100 maximum distance from the ground station (communication in zero degrees elevation angle - horizon) is calculated by equation (6) at 600 km apogee/perigee of the orbit. Fig. 4. explains the graphical depiction of the satellite horizon and the theoretical estimation of the maximal distance between the MRC-100 satellite and the ground station, as well as the speed of the MRC-100 satellite in a circular orbit.

$$d = \sqrt{(R+h)^2 - R^2} \tag{6}$$

Where d is the maximal distance between the satellite and the ground station (where h = 600 km, R = 6,371 km, and d = 2830 km).

In a circular orbit, the speed of a satellite is calculated by equation (7).

$$v = \sqrt{\frac{g \cdot R}{1 + H/R}} = 7.55 \ \frac{km}{s} \tag{7}$$

Where g is the gravitational acceleration on the Earth's surface.

III. MRC-100 Communication System and Ground Stations

The communication system of the MRC-100 is based on an external microcontroller and Acsip LoRa and FSK radio module type S68F. As shown in Fig. 7 and Fig. 8, the communication antenna is a V-shaped dipole type 2 x quarter wavelength radiator made by space-qualified bicycle brake Bowden that emits a "quasi"-omnidirectional 3D radiation pattern. This eliminates the fading effect brought on by the 3-PQ's uncontrolled movement on the LEO. The 3D radiation pattern of the antenna on the cube-skeleton and the communication subsystem antenna can be seen in Fig. 6. As shown in Fig. 5. two independent telecommand receivers and two independent telemetry transmitters are linked to the antenna realizing cold-redundant, half-duplex functioning on the UHF radio amateur band due to the subsystem-level redundancy [9], [10], [12].

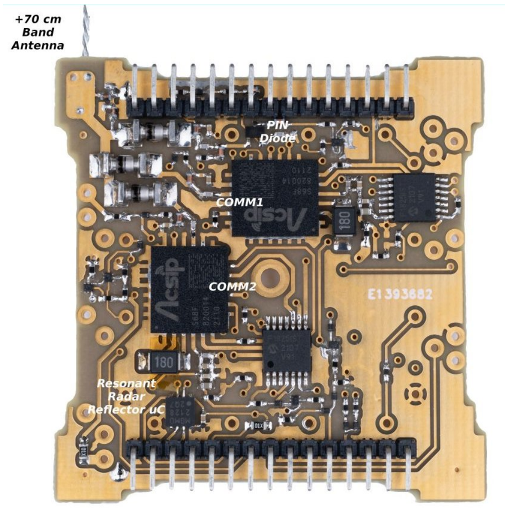

Fig. 5: The printed circuit board of the flight module.

The MRC-100 telecommand and telemetry system uses OOK (On-Off Keying), 2-GMSK (Gaussian Minimal Shift Keying as Frequency Shift Keying), and LoRa-type linear FM (Frequency Modulation) chirp. The 5000 $\frac{bit}{s}$ 2-GMSK modulation and OOK (Morse code) is used to establish a slow basic telemetry data connection. The bandwidth of the communication system of MRC-100 is licensed for operation at 12.5 kHz for uplink and 20 kHz for downlink in accordance with the international amateur radio union (IARU), and the international telecommunication union (ITU). [12], [13].

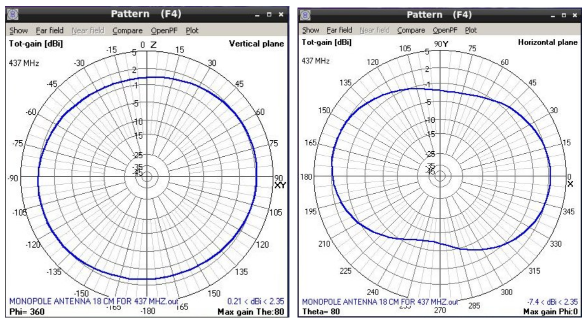

Fig. 6: The radiation pattern of the communication subsystem on Horizontal and Vertical plane.

The primary ground station (GND) is in Budapest (BME) University, as shown in Fig. 9. It has a 4.5-meter parabolic reflector-type aperture antenna with a circular back-fire helix primary radiator operating within the UHF 437 MHz band. This antenna has a notably focused main lobe, with angular dimensions of 8 degrees (-3 dB), 18 degrees (-10 dB), and 22 degrees (between null points). The antenna

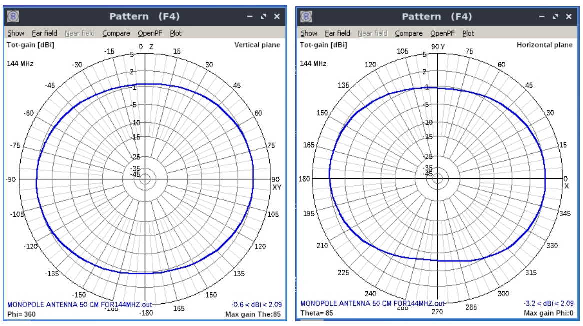

Fig. 7: The radiation pattern of the 2 meters Band on Horizontal and Vertical plane.

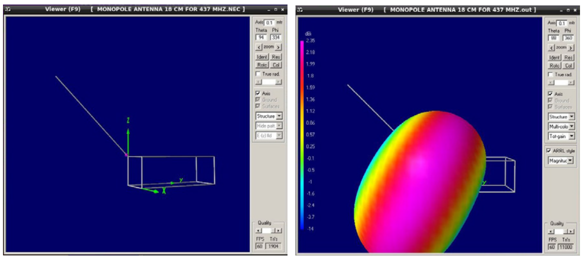

Fig. 8: The antenna on cube-skeleton and the 3D radiation pattern.

Fig. 9: Automated satellite tracking and remote-control. [6].

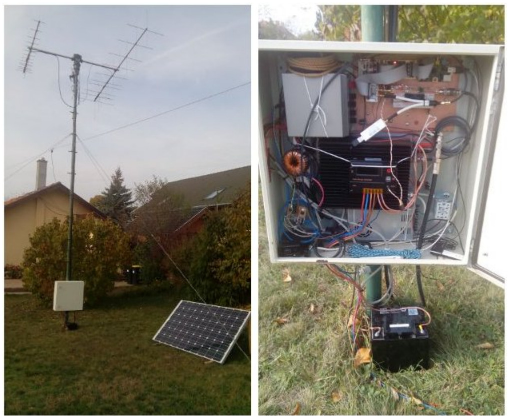

Fig. 10: The secondary GND satellite tracking [6].

gains 21 dBi for linearly polarized RF signals (or 24 dBi for circular polarization) within the region between the null points. In addition to the BME main ground station, Fig. 10. The secondary GND is located in Erd, approximately 20 kilometers from Budapest. [8], [9].

The main ground stations (GNDs) are fully automated and remote-controlled through the Internet. The core of their control system is a Raspberry PI single-board computer (SBC), capable of performing a wide range of functions. This includes the accurate azimuth-elevation antenna rotation, the detailed tracking of the satellite's path, the calculation of the Doppler shift in the RF signal, and the control of the complete radio transceiver suite including a low noise amplifier (LNA), power amplifier (PA), and coaxial relay. The primary GND's output RF power is 400 W RF + 21 dBi antenna gain, while the secondary GND's output RF power is 120 W RF + 16 dBi antenna gain. These GNDs are known about the actual operational digital data link of the MRC-100 3-PQ (5^{th}) Hungarian satellite. [8], [9].

IV. RESONANT RADAR REFLECTOR BASED ON BPSK

The main idea of the resonant radar reflector: the antenna of the communicational system can be used as a resonant reflector if the loading RF PIN diode can form short-circuit reflection (-1) and open-loop reflection (+1) as BPSK modulation of its Radar Cross Section (similar to the conventional RFID, but the distance between the reader and the tag can reach 3000 km). From the Earth Station, it is necessary to have an illuminator RF CW signal. This signal will be reflected by the onboard antenna with binary code modulation, and other ground stations with SDRs can sense this signal. If the code is known by the ground station (GND), it can detect and identify the satellite. The satellite has no RF radiation, and the consumed DC power is a few mW. We devised this resonant radar reflector and have designed a demonstrational system using a transmitter & receiver of software-defined radio (TX-RX SDR).

A. The proposed system concept

The idea behind the proposed resonant reflector is to use an antenna for a VHF/UHF communication subsystem. No radio frequency signal is radiated onboard the satellite, so power consumption is reduced to a few milliamperes (mA). Only +3 mA is used if the loading RF PIN diode can form the shape of a short-circuit, and 0 mA if the PIN diode is open-loop. With a regulated standard bus voltage of +3.3V, the power usage is under ten mW or an average of +3.5 mA. The continuous wave (CW) illuminator RF source used by the system is based on the ground, and the onboard antenna receives the CW RF signal from the Earth. Then, the microcontroller (uC) onboard the satellite alternates the PIN diode regularly to produce binary phase shift keying (BPSK) modulated signal reflection, which enables the backscattered signal to be received by additional ground stations.
Additionally, the system can detect the satellite if the ground station receiver uses a matching filter to determine the satellite's BPSK code. On the other hand, only if the receiver

knows the satellite's BPSK code can the satellite be identified. Fig. 11. and Fig. 12. explains the proposed system's block diagrams and the ground illuminator RF source.

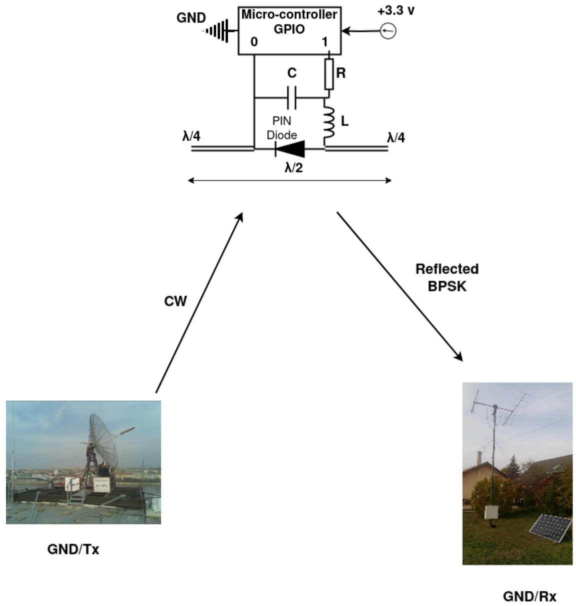

Fig. 11: Block diagram of the proposed system.

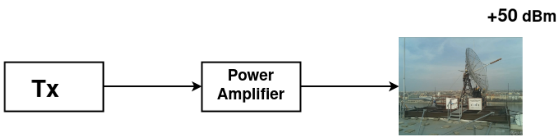

Fig. 12: Block diagram of the illuminator RF source.

The receiver part (ground segment) is realized within the proposed system as a coherent receiver, with a matched filter to precisely identify the satellite's Binary Phase Shift Keying (BPSK) code. This single-sideband (SSB) receiver receives and processes the backscattered modulated signals. It operates with an audio generator with an input signal that has a bandwidth of 2700 Hz. This signal is interfaced with an analog-to-digital converter (ADC), with seamless integration facilitated through the computer's sound card. The resulting outcome is the construction of the 'Received Vector Range and Velocity (R.V.) matrix.' In this matrix, the 'range' part is the time delay, while the 'velocity' part is the Doppler shift. This matrix contains the received BPSK code after performing a thorough and precise analysis of the received backscattered signal. Fig. 13. Shows the block diagram of the receiver.

V. Link Budget Estimation of the Proposed System

As mentioned before, the proposed trajectory of MRC-100 is polar and circular, with 600 kilometers of distance (apogee and perigee). The maximum distance of the satellite from the ground station is approximately 3000 kilometers (on the horizon), and 600 kilometers where the satellite is

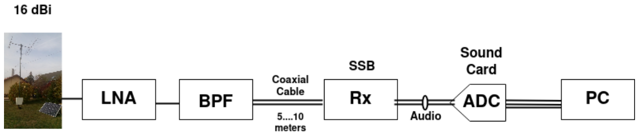

Fig. 13: Block diagram of the receiver.

perpendicular to the ground station (on the zenith). So, estimating the link budget on the UHF band (437 MHz) of the reflected BPSK modulated signal from the satellite is necessary.

The transmitted power from the ground station will be 100 W (+50 dBm). The gain of the ground station (G_{tx}) is 21 dBi, the antenna's gain onboard the satellite is 0 dBi, and (G_{rx}) is 16 dBi. The modulation loss is 10 dB, and equation (8) can estimate the free space loss on the horizon:

$$a_0 = 20\lg\frac{4\pi d}{\lambda} = 155\ dB \tag{8}$$

The received power (P_{r_x}) by the onboard satellite's antenna (0 dBi), where the satellite is at the horizon (3000 km) with free space loss 155 dB, and the transmitted power from the ground station is 100 W (+50 dBm) with antenna gain (21 dBi), can be estimated by equation(9).

$$P_{r_x} = P_{t_x} + G_{t_x} - a_0 = -84\ dBm \tag{9}$$

According to the estimated received power (-84 dBm) by the onboard satellite's antenna, we can estimate the reflected power from the satellite to the ground station when the modulation loss is 10 dB and the satellite at the horizon.

$$P_{reflected} = P_{r_x} - Modulation\ Loss = -94\ dBm \tag{10}$$

The reflected power from the satellite to the ground station when the modulation loss of 10 dB is (-94 dBm), So the received reflected power by the ground station can be estimated by (11), the antenna gain of the ground station 16 dBi.

$$P_{r_x} = P_{reflected} + G_{gnd} + G_{sat} - a_0 = -233\ dBm \tag{11}$$

The ground station can receive thermal noise power (P_n) radiated by the environment. (12):

$$P_n = 10\lg(kTB) + 30 = -144\ dBm \tag{12}$$

Where k is the Boltzmann-constant, B is the bandwidth (1000 Hz), and T is the 300 K noise power level of the Earth.

The signal-to-noise ratio (SNR) can be estimated by (13) :

$$SNR = P_{rx} - P_n = -89\ dB \tag{13}$$

The gold code generator inside the satellite's microcontroller is a linear feedback shift register (LSFR) with 10 bits length and the code length will be estimated by equation(14) .

$$Code\ Length = 2^{10\ bits} - 1 = 1023 \quad (14)$$

The processing gain can be estimated by (15) :

$$Processing\ Gain = 10\lg(Code\ Length) = 30\ dB \quad (15)$$

The received reflected power by the ground station is (-233 dBm), and the processing gain is 30 dB; the received power at the matched filter can be calculated by (16):

$$P_{r_x} = P_{rx}gnd + Processing\ Gain = -202\ dB_m \quad (16)$$

After the matched filter, we can estimate the bandwidth of the received signal, the thermal noise power level, and the signal-to-noise ratio (17) - (19) .

$$BW_{MF} = \frac{1000\ Hz}{\text{Code Length}} \simeq 1\ Hz \quad (17)$$

$$P_n = 10\lg(kTB) + 30 = -174\ dBm \quad (18)$$

Where B is the Bandwidth of the received signal after the matched filter (1 Hz), k is the Boltzmann-constant, and T is the 300 K noise power level of the Earth.

The signal-to-noise ratio after the matched filter can be calculated by (19):

$$SNR = P_{rx} - P_n = -29\ dB \quad (19)$$

The code length time can be estimated by (20) :

$$Code_T = \frac{Code\ Length}{\text{BW}} = 1.024\ s \quad (20)$$

TABLE I
HORIZON / ZENITH LINK BUDGET ESTIMATION ON UHF BAND.

Parameters	Horizon 3000 Km	Zenith 600 Km
Frequency	437 MHz	437 MHz
Wavelength	0.69 m	0.69 m
P_{t_x}	+50 dBm	+50 dBm
G_{gnd1}	21 dBi	21 dBi
G_{sat}	0 dBi	0 dBi
G_{gnd2}	16 dBi	16 dBi
a0 to Satellite	155 dB	141 dB
P_{r_x}@ sat	-84 dBm	-70 dBm
modulation loss	10 dB	10 dB
$P_{ref}from$ sat	-94 dBm	-80 dBm
P_{r_x}@ gnd	-233 dBm	-205 dBm
Bandwidth	1000 Hz	1000 Hz
Noise Temp	300 K	300 K
Thermal Noise Power	-144 dBm	-144 dBm
SNR	-89 dBm	-61 dBm
Gold Code Generator Length	10 bits	10 bits
Code Length	1024 chips	1024 chips
Processing Gain	30 dB	30 dB
Code Time	1.024 s	1.024 s
P_{r_x}@ MFout	-202 dBm	-175 dBm
BW@ MFout	1 Hz	1 Hz
P_n@ MFout	-174 dBm	-174 dBm
SNR@ MFout	-29 dB	-1 dB

The proposed reflector's system can be evaluated within the Very High Frequency (VHF) band when the satellite is at a distance of 3,000 kilometers. The transmitted power from the ground station amounts to 100 watts, equivalent to +50 decibels-milliwatts (dBm). The ground station exhibits a transmit gain (G_{tx}) of 16 decibels isotropic (dBi) and a receive gain (G_{rx}) of 13 dBi, and the satellite's antenna gain is measured at 0 dBi. The modulation loss introduces an attenuation of 10 decibels (dB), while the Gold code length is 10 bits. Consequently, the estimation of the link budget is summarized in Table II.

TABLE II
HORIZON / ZENITH LINK BUDGET ESTIMATION ON VHF BAND.

Parameters	Horizon 3000 Km	Zenith 600 Km
Frequency	144 MHz	144 MHz
Wavelength	2.08 m	2.08 m
P_{t_x}	+50 dBm	+50 dBm
G_{gnd1}	16 dBi	16 dBi
G_{sat}	0 dBi	0 dBi
G_{gnd2}	13 dBi	13 dBi
a0 to Satellite	145 dB	131 dB
P_{r_x}@ sat	-79 dBm	-65 dBm
modulation loss	10 dB	10 dB
$P_{ref}from$ sat	-89 dBm	-75 dBm
P_{r_x}@ gnd	-221 dBm	-193 dBm
Bandwidth	1000 Hz	1000 Hz
Noise Temp	300 K	300 K
Thermal Noise Power	-144 dBm	-114 dBm
SNR	-77 dBm	-80 dBm
Gold Code Generator Length	10 bits	10 bits
Code Length	1024 chips	1024 chips
Processing Gain	30 dB	30 dB
Code Time	1.024 s	1.024 s
P_{r_x}@ MFout	-191 dBm	-163 dBm
BW@ MFout	1 Hz	1 Hz
P_n@ MFout	-174 dBm	-174 dBm
SNR@ MFout	-17 dB	+11 dB

Considering the orbital movement and Two-Line Element (TLE) data, MRC-100 passes over Hungary three to six times daily, lasting approximately 10 minutes. Consequently, it becomes imperative to gauge the integration time required for the back-scattered Binary Phase Shift Keying (BPSK) modulated signal. Our experiment operates for 10 seconds every minute, equating to 100 seconds during one pass. Thus, the cumulative experimentation duration totals 300 seconds for three passes and 600 seconds for six passes. The overall integration time (T_i) on the horizon equals 10000 seconds. Referencing equation (21)., we determine the optimal Integration Gain (IG) for the received back-scattered BPSK modulated signal after the matched filter according to our experiment time.

$$IG = 10\log_{10} \cdot (\frac{T_i}{CodeTime}) = 40\ dB \quad (21)$$

Based on Equation (21), the integration gain (IG) is based on the measurement time, considering that the 1024 BPSK samples correspond to a bit time of one millisecond, resulting in a total code time of 1024 milliseconds. Consequently, IG is equivalent to +40 dB, signifying that the receiver can effectively discern the backscattered BPSK code.

VI. Preliminary concept of the Reflector and Laboratory Measurements Results

The resonant radar reflector system was functionally validated using a proof-of-concept technique based on laboratory measurements. The proposed scenario refers explicitly to creating the demonstrational system using a transmitter and receiver of software-defined radio (B200 Tx/Rx SDR) connected to two log periodic antennas. The log periodic antenna works in the range of the DVB-T band with linear gain (6 dBi). The reflector's system consists of a Raspberry Pi loaded with an RF PIN diode and a quarter-wave antenna. The RF PIN diode form short-circuits (-1 reflection) and open-loop (+1 reflection) as BPSK modulation. The maximum distance between the transmitter and the reflector's system is 22 meters, and the transmitted power (P_{tx}) is -43 dBm. Fig. 14. Explains the block diagram of the experimental model, Fig. 15 and Fig. 16. Shows the realized experimental model of the reflector's system with the antenna.

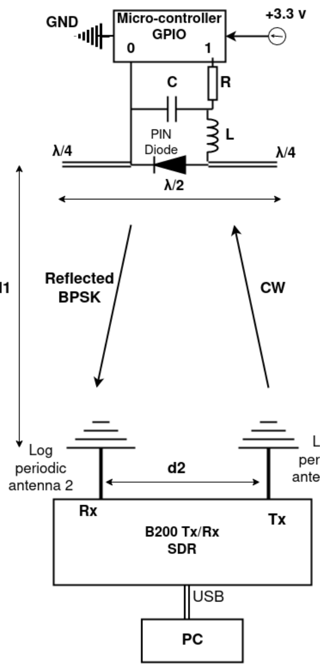

Fig. 14: Block diagram of the experimental model.

The realized measurement - SDR screen, as shown in Fig. 17. the upper part represents a waterfall diagram of the received reflected signal from the reflector, the middle part represents the real and imaginary part of the received reflected signal, and the bottom one represents the spectrum of the received reflected signal.

As shown in Fig. 18., the upper part is a waterfall diagram of the received reflected signal from the reflector when the transmitter is sending a continuous wave (CW) at 437 MHz (signal variation in time). The middle is the real and imaginary part of the received reflected signal. The fundamental part of the signal is higher than the imaginary part because the received backscattered signal is BPSK modulated signal. The bottom one is the spectrum of the received reflected signal, which seems like $\frac{\sin x}{x}$.

Fig. 15: The realized experimental model of the reflector's system.

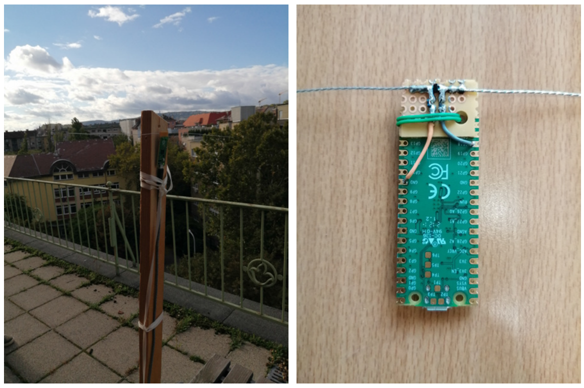

Fig. 16: The realized reflector model with the antenna.

Fig. 19. Shows the peak sidelobe level (PSL) of the received BPSK code from the reflector after the matched filter at the receiver part, and also it can be estimated theoretically by (22) , when the code length is equal to 1024.

$$PSL = 20 \log Code\ Length = 60.21\ dB \qquad (22)$$

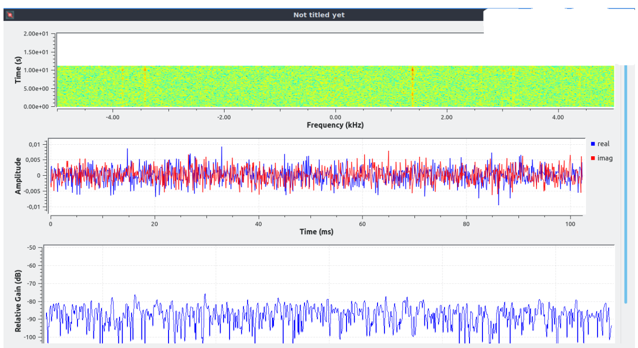

Fig. 17: The realized measurement - SDR screen.

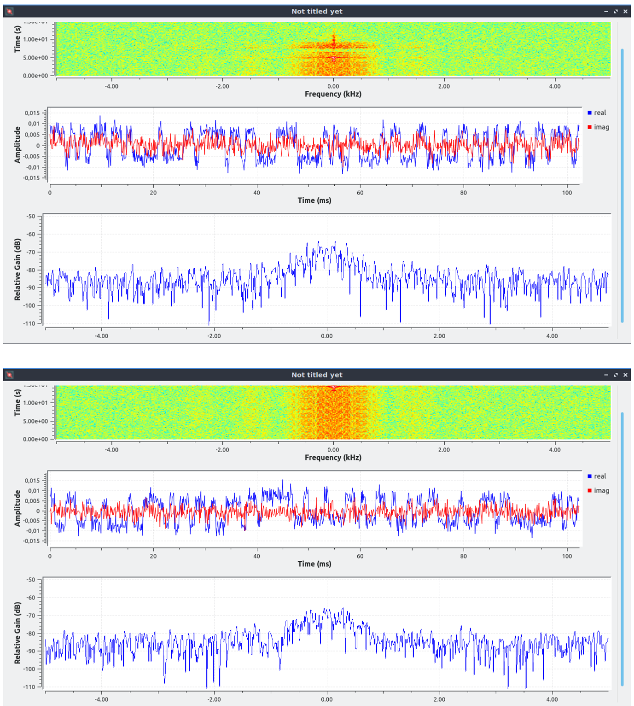

Fig. 18: 2 Figures of received reflected signal from the reflector's.

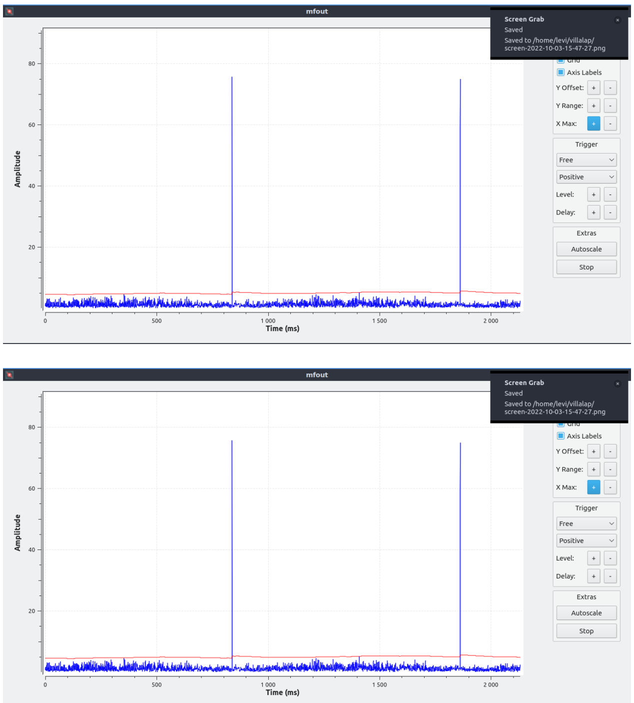

Fig. 19: 2 Figures of the received code as backscattered BPSK modulated signal.

VII. CONCLUSION

The work presented in this paper described how to identify and track PocketQube satellites based on a resonant radar reflector, and the MRC-100 satellite is a model. The goal of this paper was to establish a new method to track and identify PocketQube satellites without an expensive tracking system from the perspective of power consumption, weight, and size compatible with the global standardization of the PocketQube satellite's standard and the technology readiness level (TRL). We estimated the link budget of the system on the VHF/UHF band when the satellite on the horizon region like communication in zero degrees elevation angle and the zenith region when the satellite is perpendicular to the ground station, and we estimated the optimal integration gain that the receiver could effectively discern the backscattered BPSK code. Furthermore, the Resonant Radar Reflector was functionally validated at the laboratory. It can receive a continuous wave (CW) from the ground stations and backscatter the received signal as a Binary Phase Shift Keying (BPSK) modulated signal with a maximum distance between the transmitter and the reflector's system of 22 meters. The transmitted power is -43 dBm, and the Doppler shift is 0 Hz. We started to record the received backscattered BPSK modulated signal from the MRC-100 satellite, and the extended version will contain the Range and Velocity matrix (time delay and Doppler shift). The MRC-100 was successfully installed on the satellite platform in February 2023 and launched into outer space via a Falcon-9 rocket from the USA on 12 June 2023. The first signal from the MRC-100 was received on 22 June 2023.

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