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DEVELOPMENT OF TRACKING SYSTEMS APPLICABLE TO SPACE LAUNCH VEHICLE

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ABSTRACT

Tracking systems for launch vehicle consist mainly of radar transponder (beacon), RF switch or power divider, antennas as onboard system, and single or multiple radars as ground one. In this paper, tracking systems, which are applicable to KSLV (Korea Space Launch Vehicle)-1, are introduced and the electrical performances for developed prototypes are presented. We have also performed RF link analysis for both uplink and downlink, and estimated that the maximum distance to be able to track KSLV-1 stably is dependent on uplink characteristic in our system.

Keywords: tracking system, radar transponder, antenna, RF link

1. INTRODUCTION

We have successfully launched three sounding rockets since 1993 and advanced all along. It is indispensable to monitor the precise trajectory of moving target from lift-off to flight completion without any blackout in real time because of range safety, especially for maiden flight. Tracking system among various avionics systems such as guidance and control, telemetry, power, flight termination and video system is used to accomplish this objective and independent of others. We utilized X-band frequency which is assigned as military purpose for last three flights, but will adopt C-band frequency with a new radar system because the next flight is launch vehicle, which is mostly applied as commercial purpose in C-band all over the world (RCC-ETMG 2002).

We have already developed the prototypes of noncoherent C-band radar transponder and C-band antenna as onboard system, and confirmed that the electrical performances of developed products are coincident with tracking system of KSLV-1. Ground tracking radar is now being manufactured by foreign vendor.

2. SYSTEM CONFIGURATIONS

2.1 System Block and Tracking Mechanism

The basic tracking mechanism of target trajectory is as following Figure 1. Radar calculates slant range (d) first using the time delay (t) between interrogation and reply pulse, and then extracts

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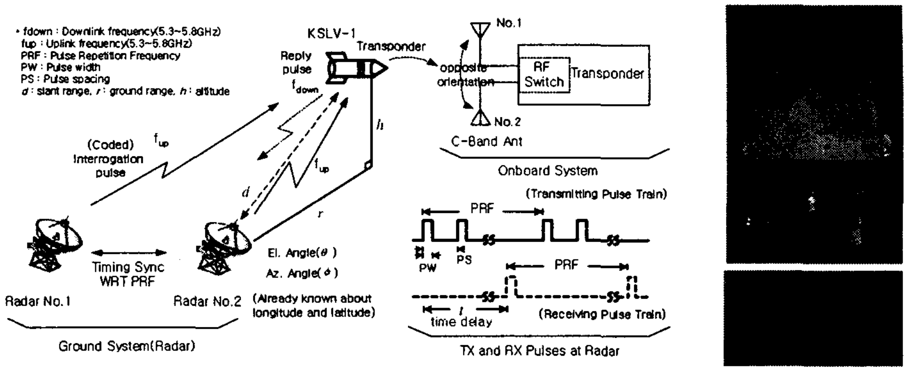


Figure 1. Tracking mechanism/systems, and photo of transponder and antenna.

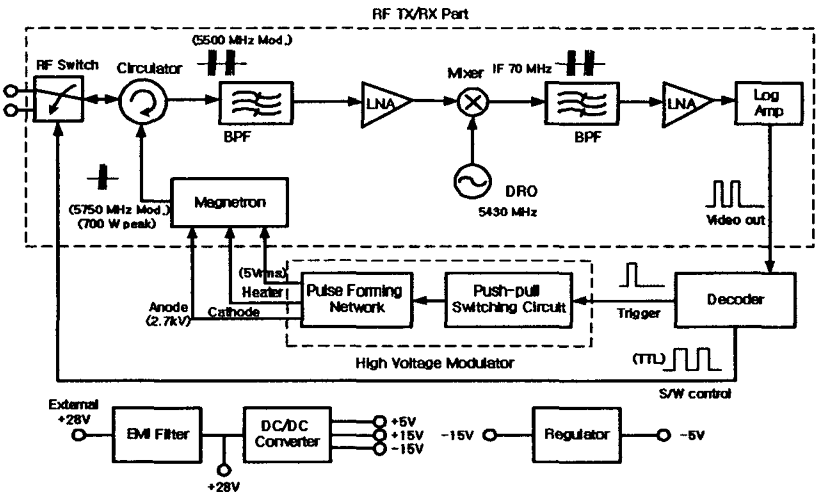


Figure 2. Block diagram of transponder.

altitude (h) and ground range (r) with elevation angle (θ). Trajectory is obtained using azimuth angle (ϕ) and the information of known longitude and latitude of radar. Interrogation pulse is the double pulse coded with pulse width (PW), pulse spacing (PS), and frequency. Transponder generates single reply pulse with different frequency if interrogation pulse agrees with what is desired in advance.

More onboard antennas than one are generally required to reduce radio wave blocking by fuselage of large launcher. We adopted two antennas with oppositive direction each other, and utilized built-in RF switch instead of power divider to decrease the effect of the ripples or nulls occurring at side and rear of two antennas. Antenna switching is accomplished as follows. The input signal from one antenna is compared with threshold level to check if interrogation signal is valid or not. If there is no valid signal for a specified time, the decoder drives to switch another port.

2.2 Radar Transponder

Transponder consists of RF TX/RX part, high voltage modulator, decoder, and power supply

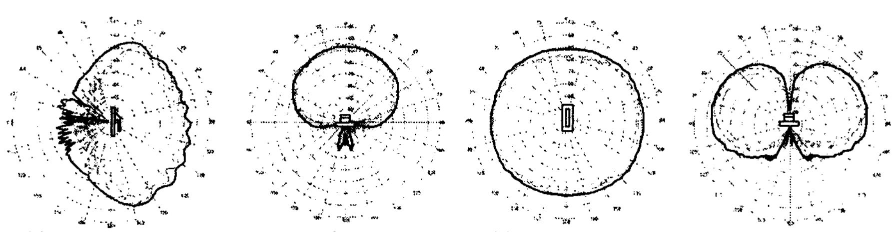


Figure 3. Antenna radiation patterns for measurement and simulation.

part. Block diagram is shown in Figure 2.

RF TX/RX part. RF switch connected directly to antennas is specified with fast switching time of maximal 50 ns, high power handling of 1kW, and good isolation of 40 dB. Circulator is used as duplexer with isolation of 20 dB and low insertion loss of 0.4 dB to transmit and receive the signal through one antenna. One RF and IF filter reject the backward transmitting signal from magnetron and out-band noise. LNA (low noise amplifier) in front-end amplifiers the receiving signal with gain of 20 dB and noise figure of 1.2dB. Down-conversion is achieved in 70 MHz using mixer with conversion loss of 7 dB and highly stable signal source DRO (dielectric resonant oscillator) with output power of 13 dBm. IF LNA amplifiers again with gain of 17.5 dB and noise figure of 3.3 dB. Finally, logarithm amplifier performs the envelop detection from the amplitude of IF signal and make the video output in the form of baseband pulse. Magnetron is utilized to generate high output with power of 700 Watt in peak because it is small, light, simple to drive itself, and easy to tune the center frequency.

Decoder. Decoder compares the input pulse with the pulse code which is programmed in CPLD with appropriate margin for pulse width and spacing. If valid pulse entered, it generates the trigger pulse to drive magnetron. It sets up threshold detection level and produces TTL signal to control RF switch, too.

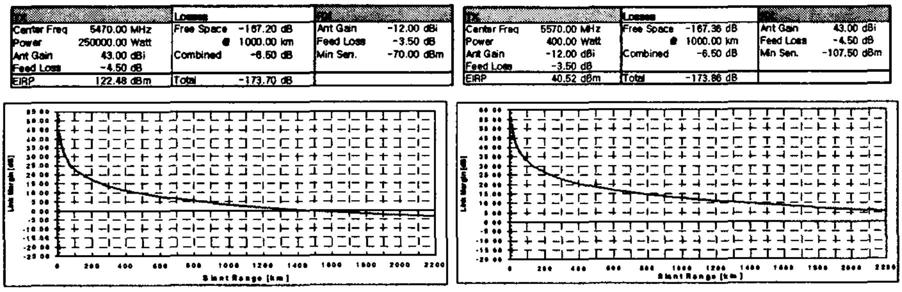
High voltage modulator. The high voltage of 2.7kV to drive magnetron is obtained using two transformers, step down converters, and bridge circuit. The process to heighten voltage is as follows. Voltage source in +28 Vdc is converted to +20Vdc by step down converter, and then ±20Vac is gained by push-pull switching circuit. ±600 Vac is also obtained using the primary transformer. Bridge circuit rectifies ±600 Vac into +600 Vdc. Finally, +2.7 kV is generated using the secondary high voltage transformer when trigger signal is active.

Power supply part. Stable ±5 Vdc and 15 Vdc are created using EMI filter, DC/DC converter, and regulator from external +28 Vdc source. −15/+5 Vdc, +15 Vdc, and +5/−5 Vdc are supplied to RF switch, LNA/DRO and IF module, various IC devices, respectively. Especially, +28 Vdc after EMI filter is provided to PWM control devices.

2.3 Onboard Antenna

Inverted-F type antennas are equipped on the outer surface of launcher (Frank et al. 2002). Developed prototype antenna has been already presented in Figure 1.

It has C-band resonant frequency, low profile structure, small size, linear polarization with vertical and horizontal, near-omni directional radiation pattern, and greater gain than -12dBi for 95% spherical coverage. Figure 3, where thick line is simulated and thin one is measured, is the measured and simulated pattern of principal plane for one antenna mounted on the subscale cylindrical model with length of 0.5 m and diameter of 0.85 m. Two results have a good agreement.



(a) Uplink (b) Downlink

Figure 4. RF link calculation for tracking system.

2.4 Tracking Radar

Precision radar is now being developed by foreign company. Main specification is as follows. Transmitter output is 250 kW in peak, antenna gain is 43 dBi, frequency range is 5.3 to 5.8 GHz, receiving sensitivity is –107.5 dBm in beacon mode and –116.0 dBm in skin mode, and beamwidth is 1 degree. Sensitivity is improved using digital signal processing by pulse integration method.

2.5 RF Link Analysis

RF link calculation is presented in Figure 4 and performed as following assumption. Multipath loss which may occur due to low elevation angle of ground antenna or fuselage reflection is ignored, and plume loss is also not considered. Rocket-borne antenna is fixed with -12dBi using the concept of 95% spherical coverage. According to this analysis, uplink margin is about 9.4 dB smaller than downlink. Therefore we could approximately estimate to be tracked at least up to 1,200 km within 3 dB margin.

3. CONCLUSIONS

We have developed the transponder with the switching technique to select the antenna on the purpose of keeping good radiation pattern without nulls and ripples. Moreover we have made the rocket-borne antenna with near-omni directional pattern. At last, it is confirmed that developed products satisfy the electrical requirements of space launcher and they are all applicable to KSLV-1.

REFERENCES

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RCC-ETMG 2002, C (G)-band & X (I)-band Noncoherent Radar Transponder Performance Specification Standard (New Mexico: RCC)