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Array Antenna Design for Ku-Band Terminal of L.E.O Satellite Communication

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Abstract

This study is a Ku-band array antenna for the manufacture of low-orbit satellite communication terminals, designed to have miniaturization, high gain, and wide beam width. The transmission of low-orbit satellite communication has a right-rotating circularly polarized wave, and the reception has a left-rotating circularly polarized wave. The 4×8 array antenna was separated for transmission and reception, and it was combined with the RF circuit part of the transmitter and receiver, and was terminated in the form of a waveguide for RF signal impedance matching in the form of a transition from the microstrip line to the waveguide. The 30° beam width of the receiver maximum gain of 19 dBi and the 29° beam width of the transmitter maximum gain of 18 dBi are shown. Through this antenna configuration, the system was configured to suit the low-orbit satellite transmission/reception characteristics.

Keywords: *Array antenna, L.E.O, Teminal, Transition, Waveguide*

1. INTRODUCTION

Recently, the satellite communication market is moving to a low orbit cluster satellite communication system capable of higher communication speed and low delay, instead of the geostationary orbit satellite communication that has been dominant so far. While interest in high-speed internet using low-orbit swarm communication satellites is growing, SpaceX, OneWeb, Telesat and Amazon are expected to launch up to 46,100 satellites over the next few years. This is more than five times the number of satellites sent into space in the past 60 years, and the low-orbit cluster consisting of numerous satellites to provide high-speed Internet is heating up the space race as part of the private-led New Space. Unlike SpaceX's business for commercial communications, the Chinese government has established a company that can operate a constellation of 13,000 satellites. The State-owned Assets Supervision and Administration Commission, a government agency that supervises state-owned enterprises, announced on April 29, 2021 the establishment of the China Satellite Network Group and the establishment of a cluster satellite system named GW (Guo Wang) [4]. In Korea, domestic companies are also actively participating in the satellite development field in line with the new space era [5]. Hanwha Systems, which has satellite and defense technology, signed an investment contract with OneWeb in August 2021. This is because Hanwha Systems is actively participating in the low-orbit cluster satellite communication system market by utilizing its accumulated development capabilities, such as satellite

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antennas, and anticipates the possibility of supplying satellite Internet networks in the Asian region [6]. The Korean government also announced a satellite communication development strategy to prepare for the 6G era. A plan to launch a low-orbit satellite was proposed to actively support the growth of related industries by promoting satellite communication technology and service demonstration [7]. Unlike previous initiatives such as GlobalStar and Iridium aimed at bridging the global digital divide, the low-orbit convergence satellite system's success depends on the creation of new business models and significant cost savings. As a business model for this, SpaceX is aiming for online global through the distribution of low-cost terminals of less than $200 per unit, and in this paper, we propose an antenna structure corresponding to the main core part of low-orbit satellite communication terminals.

2. DESIGN OF TX & RX ANTENNAS

Transmission and reception of low orbit satellites are divided into down link and up link in dual band and dual polarization, Ku band 10.7 ~ 12.75 GHz and 14.0 ~ 14.5 GHz, and LHCP and RHCP polarization are used. Because the transmission and reception characteristics of low earth orbit satellites are mobile, the 3dB beam width of the transmission and reception antenna of the terrestrial satellite terminal must be wide or beam forming must be implemented. To implement a low-cost terminal, the PCB structure was designed as an inverted microstrip to widen the 3dB beam width of the antenna and increase the gain of a single element, and impedance matching was performed with a waveguide transition to minimize coupling loss of the RF modules (BUC, LNB) of transmission and reception. In addition, considering the movement characteristics of low-orbit satellites, an electrical signal switching module suitable for this design structure is mounted. Table 1 shows the transmit/receive antenna design specifications for terminal manufacturing.

Table 1. Design Specificaition

Terms	Parameter	Design Goals & Spec.
dB	Rx. Antenna Gain (Peak)	19.0dB
dB	Tx. Antenna Gain (Peak)	18.0dB
-	Tx. VSWR	2 : 1 under
-	Tx. VSWR	2 : 1 under
-	Antenna & RF module Combination	M.S to W.G transiton
-	Antenna Port type	Waveguide
mm	Antenna Size	180 X 72 X 5 mm

The transmit and receive antennas were designed separately, and the air gap was designed to be 1 mm in the PCB structure to implement a broadband single device. Considering trade-off characteristics between high gain and wide beamwidth, the Tx and Rx antennas were fixed in two arrays to have a 3dB beamwidth wider than 30°. Impedance matching and transition were performed through the waveguide cap to facilitate impedance matching with each transmit/receive RF module.[8],[9]

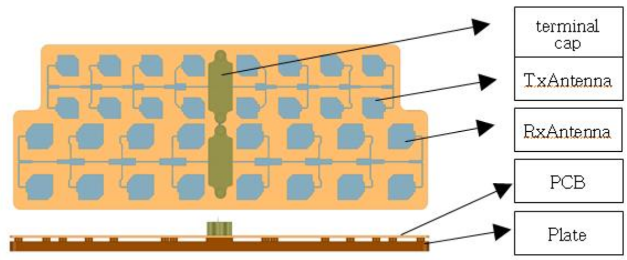


Figure 1. Structure of Tx & Rx antenna

The antenna structure is shown in Figure 1, and transmission line loss is minimized by using Telflon PCB. The array antenna was designed by configuring the transmission line of the array structure as a series-parallel feed network, and the Tx and Rx frequency band characteristics, gain, and beam width were optimized according to the design specifications through EM simulation. As shown in Figure 2, a transmission gain of 18dBi, a reception gain of 19dBi, and a beam width of 29° to 30° were derived, and the PCB was fabricated after designing the antenna mechanical drawing.[10]

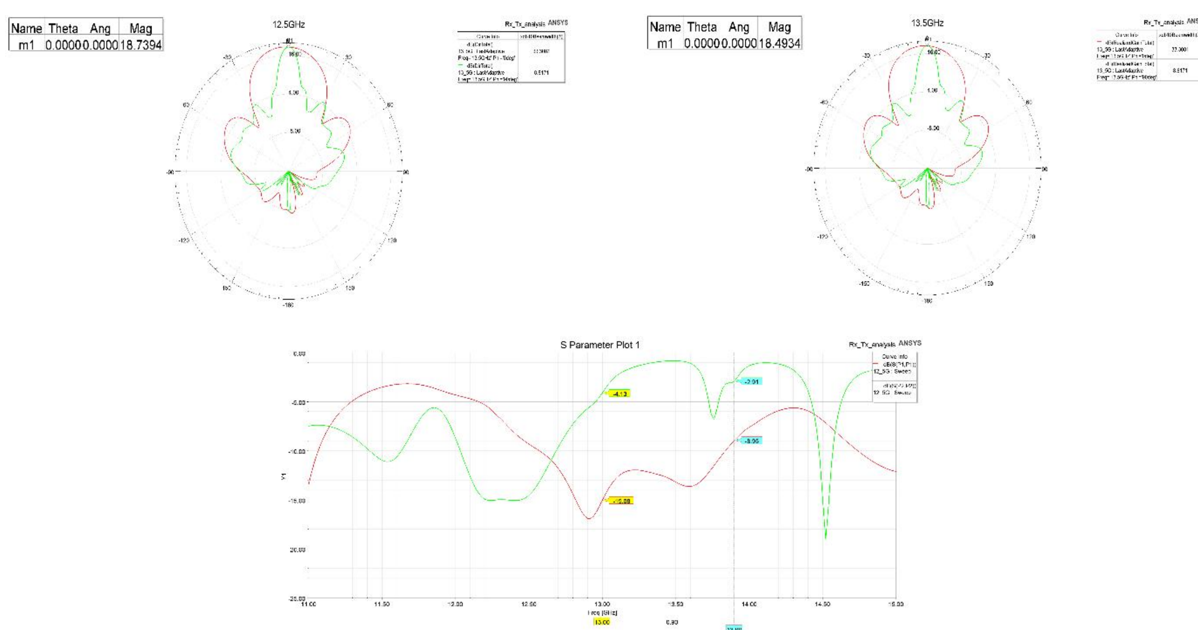
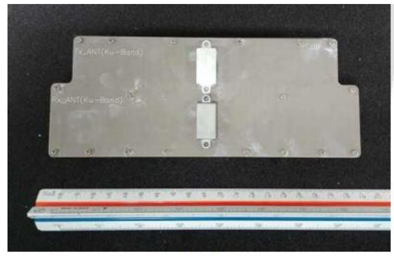


Figure 2. Simulation of Tx & Rx antenna (12.5GHz & 13.5GHz Gain , S11&S22)

3. FABRICATION AND MEASUREMENT OF TX & RX ANTENNAS

To fabricate the antenna, an aluminum plate, waveguide cap, and antenna PCB were fabricated. To measure the antenna gain and return loss, the antenna feed port was connected with a WR-75 adapter and electrical characteristics were measured. The fabricated antenna is shown in Figure 3 and measured by connecting as shown in Figure 4 for return loss and gain measurement.



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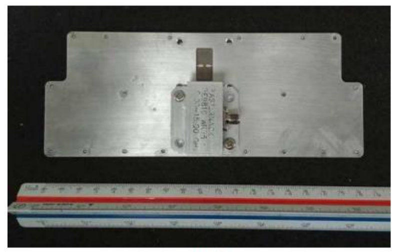

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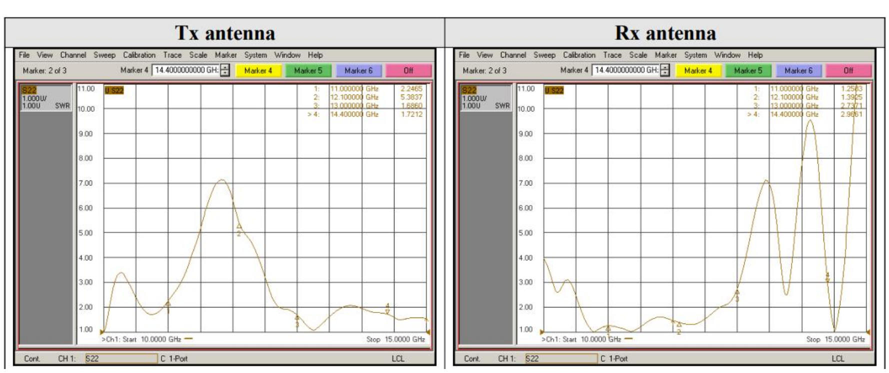
Figure 3. Fabrication of Tx & Rx antenna

The antenna gain was measured with an anti-reflection chamber Far field, and the measurement location was conducted at the National IT Industry Promotion Agency.

Figure 4. Measurement of Antenna Return loss & Gain



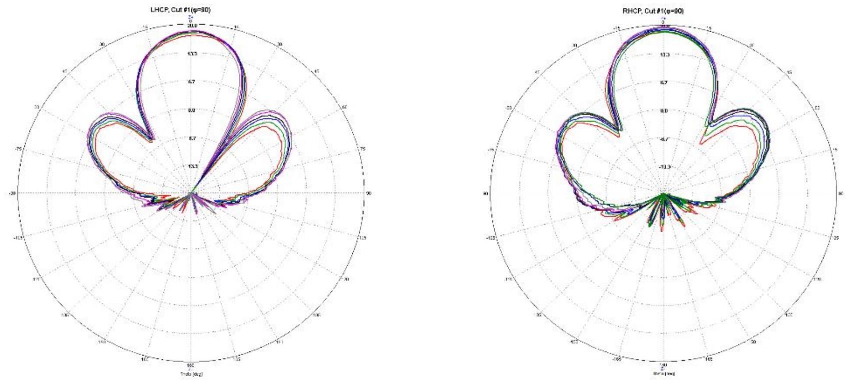


Figure 5. Measurement data of Return loss & Gain

Table 2. Data table of Gain

A. Tx antenna

Frequency (GHz)	VSWR	LHCP Gain (dBic)	HPBW (degrees)	
			Azimuth	Elevation
13.9	2.0	17.3	7.9	33.5
14.0	2.0	17.8	7.8	32.2
14.1	1.9	18.1	7.7	31.2
14.2	1.8	18.1	7.7	30.3
14.3	1.8	18.3	7.8	29.2
14.4	1.7	18.0	7.7	27.8

B. Rx antenna

Frequency (GHz)	VSWR	RHCP Gain (dBic)	HPBW (degrees)	
			Azimuth	Elevation
11.3	1.1	18.3	7.2	31.4
11.4	1.1	18.5	7.3	30.8
11.5	1.2	19.0	7.4	30.4
11.6	1.4	19.3	7.4	30.2
11.7	1.6	19.5	7.4	29.8
11.8	1.6	19.4	7.5	29.5
11.9	1.6	18.8	7.6	29.1
12.0	1.5	18.2	8.0	28.7

As shown in Figure 5, the transmit/receive band antenna gain and return loss were measured with a peak gain of 18dBi or more, a beam width of 30°, and a standing wave ratio of 2:1 or less.

3. CONCLUSION

In this paper, an antenna for a low-orbit satellite terminal for short-distance communication was designed and manufactured. The transmission and reception antennas are separated and arranged and configured to match the satellite transmission and reception characteristics of moving bandwidth, gain, and beam width, and the transmission line is transitioned with a waveguide cap to match the transmission and reception RF modules (BUC, LNB) and impedance. The target gain and beam width were configured with a 4×8 array serial/parallel feed network, and the RF signal loss was minimized to obtain the performance of 19 dBi reception and 30 ° beam width and 18 dBi transmission and 29 ° beam width. Based on this, after integrating two or four 4×8 array antennas in the terminal, seamless satellite tracking can be implemented through the RF signal switching diode.

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