L-band Planar Array Antenna with High Efficiency for DCS_VSAT Applications

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***Abstract*—In this paper, we describe the design of an L-band (1.5 GHz & 1.6 GHz, Rx & Tx band for GK3 DCS_VSAT) planar array antenna with high efficiency. The radiating element has a cross-slot structure with dual orthogonal feed to generate left hand circular polarization (LHCP). In addition, the overall array antenna consists of a 4x4 planar arrangement and has a uniform amplitude distribution in the same phase. Considering the directivity of the radiating element, the optimized array spacing in the horizontal and vertical directions is 157.5 mm (0.84λ_o), and a low-loss feeding network is designed using a shielded suspended strip line (SSSL). The measured antenna gain is greater than 20.0 dBi in the operating band, the axial ratio is less than 1.41 dB within the 3-dB beam-width, and the antenna efficiency is more than 92%.**

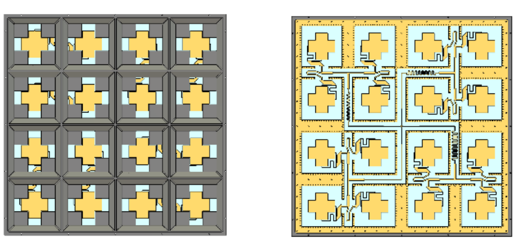
Keywords*—*cross-slot element, planar array antenna, axial ratio, shielded suspended strip line, sequential rotation

I. Introduction

Planar array antennas to be used in terrestrial data collection systems (DCS) require high-efficient antenna gain characteristics in the L-band. In order to design a planar array antenna operating in such a band, the radiating element and the feed circuit network constituting the array shall provide about 10 % of the operating band characteristics. The low-loss feeding network using a shielded suspended strip line (SSSL) has been applied in the previous studies [1-4]. This paper briefly describes the design, fabrication, and testing of high-efficient array antenna using cross-slot radiating elements.

II. Optimal Design

Fig. 1 shows the design geometry of an L-band 4x4 planar array antenna with feeding distribution of uniform amplitude and the same phase.



(a) Top-view(without radome) (b) Internal-view(SSSL feed network)

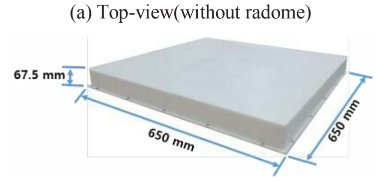
Fig. 1. Design geometry of L-band 4x4 planar array antenna

The radiating element is a cross-slot structure which has a dual orthogonal feed with a 90^o phase difference to obtain LHCP. The input return loss of the radiating element is more than 20.0 dB within the operating band. In addition, the element gains at f_{Rx} and f_{Tx} have 8.3 dBi and 9.1 dBi, respectively. The optimized arrangement spacing, taking into account the directivity of the radiating element, is 157.5 mm, which corresponds to a length of 0.84 wavelengths at the center frequency (fc = 1.5975 GHz). The overall array antenna consists of the upper layer mechanic with cross-slot array and for upper shield of SSSL, the middle layer(RF PCB) for feeding circuit realization of SSSL, and a lower layer mechanic for upper shield of SSSL. The RF PCB substrate used to implement the low-loss feed circuit of the SSSL structure is Taconic, HF350F (ε_r = 3.5, H = 508 mm, T = 0.018 mm, tanδ = 0.0029 @2 GHz). In addition, in order to provide excellent axial ratio characteristics in a broadband, a technique of sequentially rotating the quarter array by 90^o and compensating the phase is used. The input of the planar array antenna is fed from the central part of the antenna, and the input port is an SMA(F) connector having a characteristic impedance of 50 Ω.

III. Fabrication and Elcectrical Performance

Fig. 2 shows the fabricated L-band 4x4 planar array antenna. The outer radome is made of ABS, and the dimensions of the planar antenna array are 650 x 650 x 67.5 mm (3.46 λ_c x 3.46 λ_c x 0.36 λ_c).

(a) Top-view(without radome)



(b) External-view(with radome)

Fig. 2. Fabricated L-band planar array antenna

The input return loss of the L-band planar array antenna is shown in Fig. 3. The measured input return loss is very similar to the simulated one, and it can be seen that the input matching performance is more than 18.2 dB within the operating band.

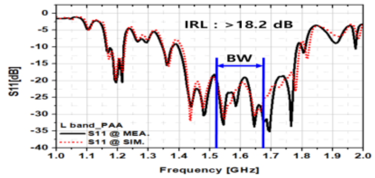
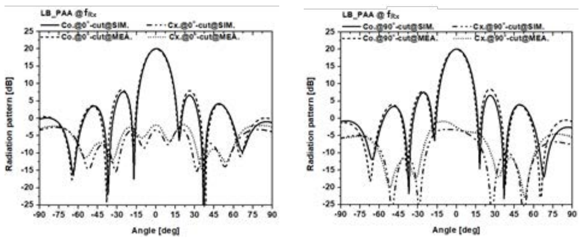
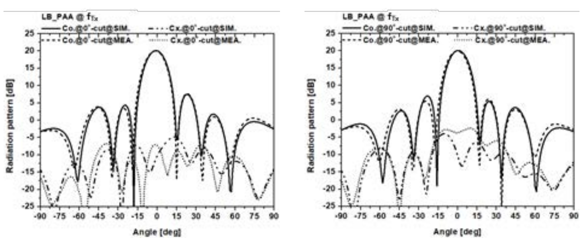


Figure 3. Input Return Loss Characteristics of L-Band Planar Array Antenna (Measurement and Simulation Comparison)

Fig. 4 shows the radiation patterns of a planar array antenna measured in an anechoic chamber. The measured radiation patterns show regular beam patterns with left and right balance, and the results are very similar to the simulation ones. In addition, it can be seen that it shows the null distribution (null position and depth) to explain the exact phase feeding design.

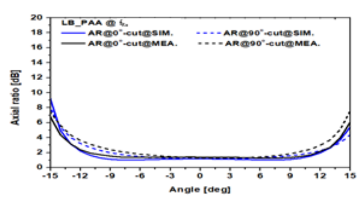


(a) f= f_{Rx} (DCS Rx-band)

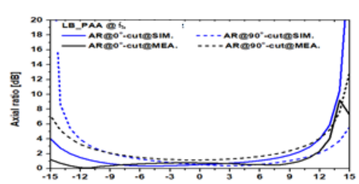


(b) f= f_{Tx} (DCS Tx-band)

Fig. 4. Measured radiation patterns of planar array antenna



(a) f= f_{Rx} (DCS Rx-band)



(b) f= f_{Tx} (DCS Tx-band)

Fig. 5. Axial ratio characteristics of planar array antenna

The measured key parameters for the radiation pattern characteristics of the 4x4 planar array antenna are summarized in Table 1.

Table 1. Summarized radiation pattern characteristics of 4x4 planar array antenna

Item	*Simulation*	*Measurement*
Operating band	L-band (160MHz BW)	L-band (160MHz BW)
Antenna gain	20.1 dBi @ f_{Rx} 20.1 dBi @ f_{Tx}	20.0 dBi @ f_{Rx} 20.0 dBi @ f_{Tx}
Polarization	LHCP	LHCP
Axial ratio (Boresight)	1.17 dB @ f_{Rx} 0.52 dB @ f_{Tx}	1.40 dB @ f_{Rx} 1.15 dB @ f_{Tx}
Axial ratio (3-dB beamwidth)	1.17 dB @ f_{Rx} 1.25 dB @ f_{Tx}	1.41 dB @ f_{Rx} 0.77 dB @ f_{Tx}
Sidelobe level	12.4 dB Min. @ f_{Rx} 12.6 dB Min. @ f_{Tx}	11.7 Min. @ f_{Rx} 12.3 dB Min. @ f_{Tx}
Antenna efficiency	95.3 % @ f_{Rx} 94.2 % @ f_{Tx}	92.4 % @ f_{Rx} 92.1 % @ f_{Tx}

In the design, the total antenna efficiency using the SSSL feed network is more than 92 %, which corresponds to the loss of 0.25 dB. The total loss of the planar array antenna includes the radiation, feeding and input matching loss.

IV. Conclusion

In this paper, the 4x4 planar array antenna with high efficiency (more than 92 %) was described. The high efficiency was realized by the low-loss feed network using SSSL. The results of this research will be used for the development of high-efficient planar array antennas operating in various frequency bands in the future.

Acknowledgments

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