

SYSTEM DEVELOPMENT OF TRANSMITTING CONFORMAL SATCOM ARRAY ANTENNA STRUCTURES(CSAAS)

EMUS 2020

M.-S. KIM^{*}, J.-W. SEO[†]

^{*} Agency for Defense Development (ADD)
Yuseong-gu, Daejeonshi, 34186, South Korea
e-mail: castle@add.re.kr, <http://add.re.kr>

[†] e-mail: jwseo@add.re.kr, <http://add.re.kr>

Key words: Tile Antenna, Housing, Radome, CSAAS

Abstract. This study presents the development results of Conformal SATCOM Array Antenna Structure(CSAAS) for transmitting. Tile Type antenna with 8x8 antenna element array has been developed instead of reflector antenna. 8x8 tile antennas are arrayed on the curved surface with one directional curvature to simulate aircraft skin configuration. Housing has the grid structure to minimize out-of-plane deformation that affects the antenna performances. Tile antennas are attached to the surfaces between grids. Radome is designed as an A-sandwich type to carry some distributed skin load and glass epoxy material with lowest dielectric constant and loss tangent was used for the best electromagnetic performance. One tile antenna is designed with a separate data control and power connection for vertical and horizontal polarization. The static structural strength of the housing and impact strength of the radome were verified by the analysis and tests. Beam pattern test, beam control test and beam steering test are performed in an anechoic chamber for the transmitting CSAAS. The results of structural and electromagnetic tests showed that the design objects met the goal successfully.

1 INTRODUCTION

SATCOM antenna installed on the global hawk, which is the reflector antenna, causes a huge front radome to protect SATCOM antenna. Whereas SATCOM antenna installed on B-2 stealth bomber is a conformal array antenna. Essential planar antenna to compose a stealth aircraft gives a little volume to the aircraft which results in aerodynamic drag reduction, operational efficiency increase and easy structural design, etc. But we barely find the applied aircraft planar SATCOM antenna because the level of difficulties of array antenna design is very high. SATCOM antenna uses geostationary satellite and the distance from geostationary satellite to Korea is 37,000 km which is very long distance to make it consider the area of the planar antenna important.

This study designed and manufactured transmitting conformal SATCOM array antenna structures to verify ground to satellite communication. The structure and the antennas are integrated into one system and the antenna performance test, beam steering test was done in

an anechoic chamber.

The location of the antenna was selected on x-47 based aircraft and the aerodynamic loads were induced. Static structural tests were performed to verify the structural strength of the CSAAS and impact load were applied to verify the impact strength.

2 DEVELOPMENT OF CSAAS

2.1 Requirements

The design objectives of CSAAS are summarized in table 1.

Table 1. Design Object

No.	Item	Design Objective
1	Structural Strength	Carry aircraft skin load
2	Stiffened Structure	Design stiffened grid
3	Antenna Frequency	Ku-band
4	Antenna Type	Tile Type
5	Antenna Performance	45 dBW(EIRP)

※EIRP: Equivalent Isotropically Radiated Power

2.2 Structures

2.2.1 Design

The structure is made of radome and housing as shown in Figure 1. The material of the radome was selected as glass epoxy composite with low dielectric constant and low loss tangent. The electromagnetic wave loss analysis was done for the structure and structural cross section and the distance from radome to the antenna skin with minimum loss was selected. Strength analysis was performed to derive stacking sequence and angles to satisfy impact strength and static strength. The tile antennas are installed into housing using screws and the connectors are attached to the backside of the housing to support data and power. The angle of side structure is decided considering physical interference when the electronic beam steers. Ventilation air holes are provisioned on the side of the housing for cooling the activating the tile antennas.

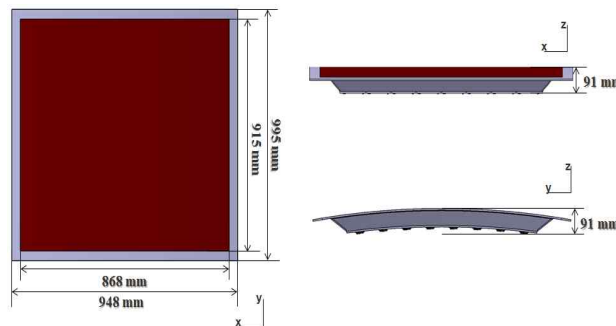


Figure 1. Conformal Array Antenna Structure

2.2.2 Fabrication

Array antenna structures are fabricated using autoclave curing process that includes grids and substructure together. The grids are cut following the grid shape before the curing process and stacked after substructure stacking.

2.2.3 Verification

Structural strength tests are performed for the array antenna structures. Out-of-plane directional deflection tests are performed to derive maximum allowable deflection of Tension/Compression/Shear loads. Figure 2 shows shear load strength test for the array antenna structures. Radome and substructure are integrated and fixed to beam structures. One actuator is connected from the bottom for a shear load and strain gages and displacement gages attached on the radome surface. Structural behaviors of the test are compared with simulation results.



Figure 2. Shear load test setup.



SCIPEDIA

2.3.1 Tile Antenna

Register for free at <https://www.scipedia.com> to download the version without the watermark

Transmitting tile antenna has one PCB(Printed Circuit Board) and four MLBs(Multi-Layer Board) stacked under antenna board. The PCB has 22 layered Rogers substrates and core-chips, power dividers, band path filters and MCU(Main Control Units) are distributed on it. Transmitting tiles has vertical and horizontal polarizations. Antenna board has core-chips for dual polarization as shown in Figure 3 and LNA(Low Noise Amplifier)s, PS(Phase Shifter)s, and DA(Driving Amplifier)s are located in each core-chips. The tile has 128 core-chips and 8 MCUs that has 1:16 divider.

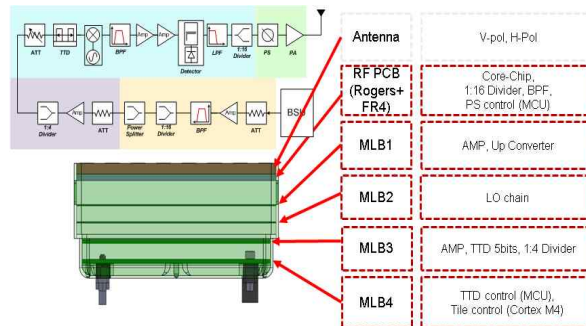


Figure 3. Multi-layered Structure of Transmitting Tile

2.3.2 Array Antenna

Transmitting satellite communication antenna is using Ku-band frequency. The band width is 500 MHz. Figure 4 shows transmitting array antenna system consisted of antenna element, cell, tiles and sectors. Four cell of one tile antenna has L-band frequency transferred from Ku-band. After going through TTD(True Time Delay) and 4:1 power divider the signal goes to sector.

Transmitting signal input starts from analog interface and BSU-T divides after going through ADC(Analog to Digital Converter) as digital signal. DDC/DUC and weighting determines sector level path compensation and polarization direction of transmitting signal. IF analog signals are sent out to sectors.

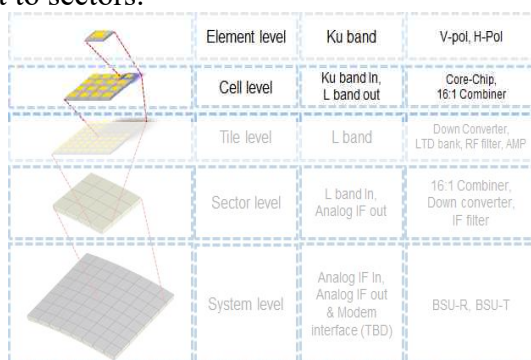


Figure 4. Hierarchical Diagram of Transmitting Antenna

2.3.3 Beam forming simulation

Transmitting array antenna has TTD as beam steering control method. Figure 5 shows simulated contour polarization patterns when the scanning range of antenna steers to several different directions. Main beams to the steered directions are well positioned. The rise of sidelobe level appears to the elevation and azimuth angle direction and makes yellow strand in Figure 5.

Register for free at <https://www.scipedia.com> to download the version without the watermark

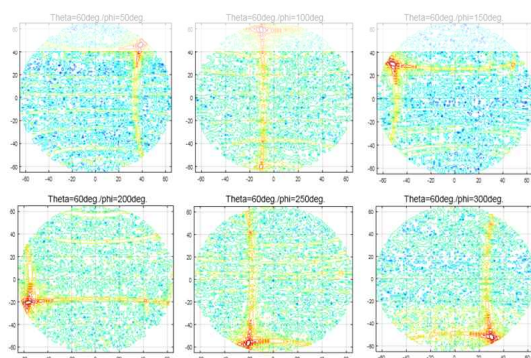


Figure 5. Polarization patterns according to steered main beam direction

2.3.4 Beam Forming Network

The use of simple PS(Phase Shifter) to steer beam direction makes beam difference for the frequencies as shown in Figure 6. That's because phase difference between tile antennas depend upon physical distance between tile antennas. Actually the phase difference for the

physical distance varies according to the operating frequencies. To compensate the time delay of phase path between antennas, TTD(True time delay) device should be used.

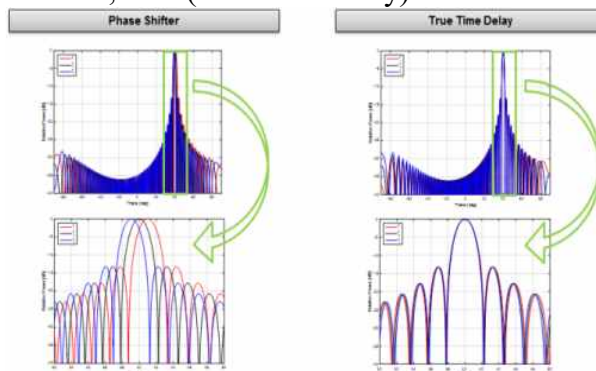
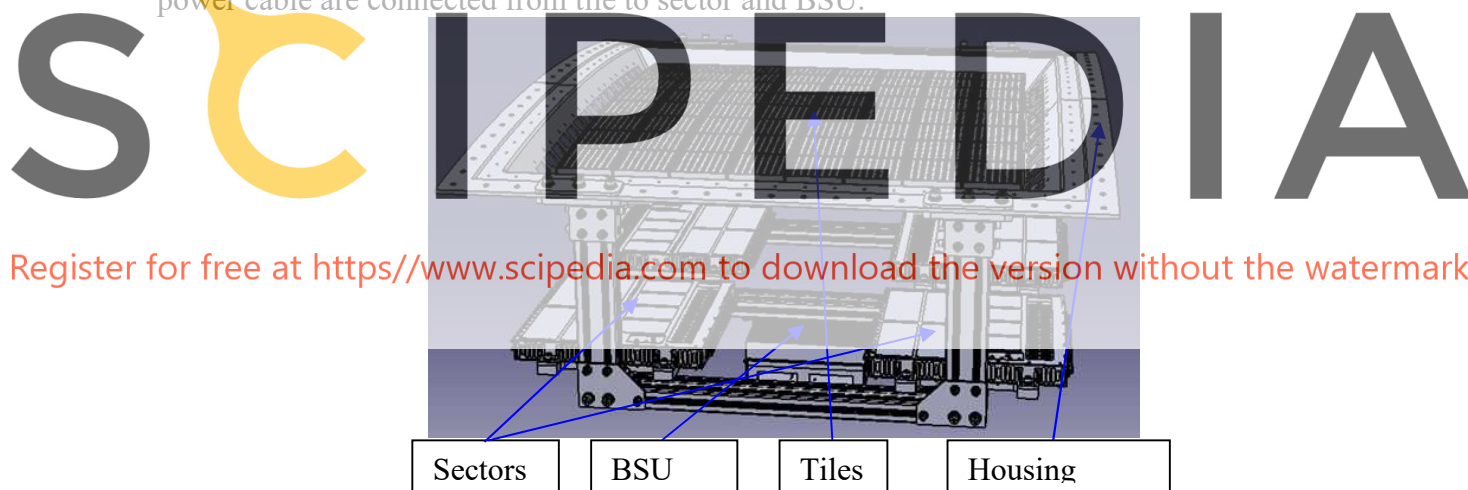


Figure 6. Beam squint comparison for PS and TTD devices

2.4 CSAAS Integration

2.4.1 Mechanical Integration

Transmitting tile antennas are installed into the bottom of housings. 64 transmitting tiles are fixed using screws and connectors are hooked to the sectors and BSU. Signal cables and power cable are connected from tile to sector and BSU.



Register for free at <https://www.scipedia.com> to download the version without the watermark

2.4.2 Antenna System Calibration

After calibration of each 64 tile antenna, one calibration for one phase of 64 tile antenna system is performed. Phase control devices are applied for the tile level because the calibration of the core-chip in the tiles are finished.

2.4.3 Antenna System Performance

Figure 9 shows RF block diagram from tile to element antenna. RF signal from sector goes to 64 tiles and each tile has 1:4 power divider before cell. One cell has polarization signal 1:16 power distributor after TTD, amp, frequency converter and filter and signal goes to antenna element through core-chip. Transmitting array antenna has 4,096 antenna elements,

8,192 core-chips and 512 frequency converter. The test result for EIRP in an anechoic chamber shows 68 dBW. Figure 10 shows far-field horizontal polarization pattern for Azimuth angle 0° and elevation angle 60°. Figure 11 shows far-field vertical polarization pattern for Azimuth angle 0° and elevation angle 30°.

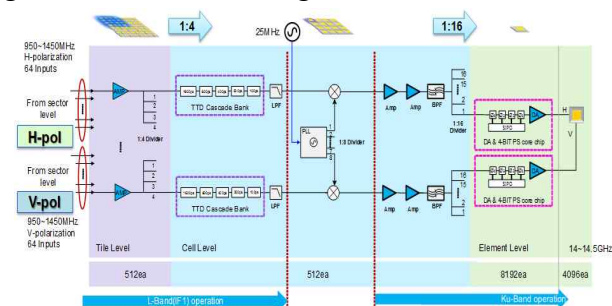


Figure 9. RF Block diagram from Tile Input to Patch Antenna



Fig. 10. Horizontal Pattern for Azi. 0°, Elev. 60°

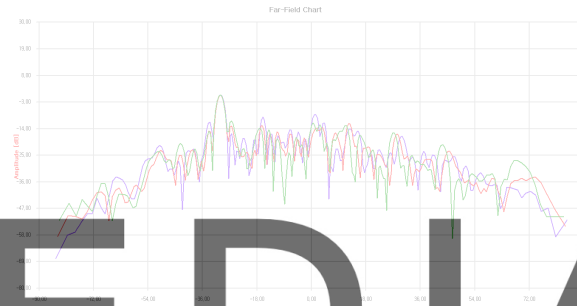


Fig. 11. Vertical Pattern for Azi. 0°, Elev. 30°

3. Conclusion

Register for free at <https://www.scipedia.com> to download the version without the watermark

The conformal antenna array antenna structures are designed, modeled and integrated into a transmitting conformal array antenna structures that can be installed into an aircraft. Mechanical performances are satisfied by designing housing as orthogrid structure and mechanical/electromagnetic performance are satisfied by installing tile antennas between grids. Impact strength is satisfied by designing radome as a-sandwich structures. Transmitting antenna can actively steer the beam from 0° to 60° maintaining beam-width. We verified all the requirements of CSAAS are met by tests.

REFERENCES

[1] Baek, S.M., Go, M.G., Kim, M.S. and Joo, Y.S. *Structural Design of conformal load-bearing array antenna structures(CLAAS)*. Advanced Composite Materials, Vol. 25, (2017):29-42.

[2] Mackenzie, Anne I., *Electromagnetic Modeling for the Conformal Lightweight Antenna System for Aeronautical Communications Technologies(CLAS-ACT) Program: Final Report. NASA/TM-2019-220293, NASA Langley,(2019).*