Design of Aircraft On-glass Antennas for FM Radio Communications

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***Abstract*-This paper proposes an aircraft on-glass antenna for FM radio communications on the aircraft. We applied a multi-loop structure to obtain a high radiation gain and a broad matching characteristic. The antenna structure was optimized using a Pareto genetic algorithm with a full wave EM simulator. The simulated data show an average bore-sight gain of -14.1 dBi and a half power matching bandwidth of 17% in the FM radio band.**

I. Introduction

Pole-type antennas and blade-type antennas have been widely used for FM radio communications in various types of aircrafts. These antennas generally have low durability and high aerodynamic resistance because they protrude outside the aircraft. To mitigate these problems, internal on-glass antennas printed directly on windows have been widely developed, especially in the auto industry. Internal on-glass antennas, however, often have relatively low radiation gain since the antenna is directly printed on glasses with a high dielectric constant and loss tangent.

In this paper, we propose an on-glass antenna based on a multi-loop structure that has high radiation gain and broad matching characteristics suitable for use in the aircraft. Striplines of the multi-loop are designed to be placed along the conducting frame of the window to obstruct pilots' field of view as little as possible. The designed antenna was inserted in a Korean military helicopter (KUH-Surion) and performance criteria, such as a matching bandwidth and bore-sight gain, were simulated with a full wave EM simulator (FEKO Suite 5.5, EM Software & Systems). The data show an average bore-sight gain of -14.1 dBi and half power matching bandwidth of 17% in the FM radio band (30-88 MHz).

II. Antenna Design and Optimization

Fig. 1 shows the geometry of the KUH-Surion. The proposed antenna is located on the left side of the window and the feed position is located at the upper side of the window frame that similarly acts as a ground plane. To estimate accurate antenna performances, the entire geometry is included as 3,300 piecewise triangular meshes into FEKO software, as shown in Fig. 1.

Fig. 2 shows the proposed antenna structure. The antenna consists of three loops with different lengths and a feed line.

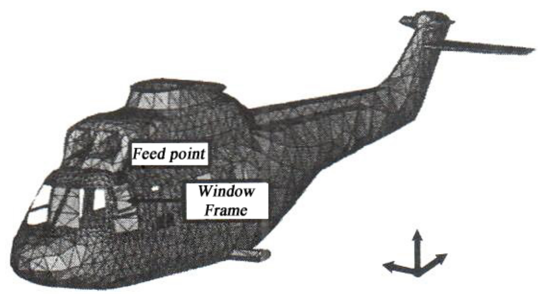

Figure 1. Geometry of Korean Utility Helicopter (KUH-surion)

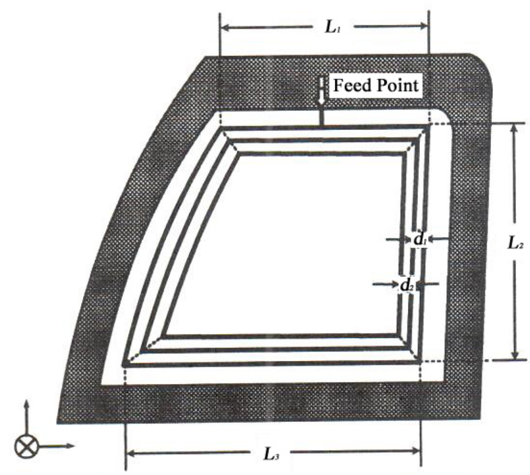

Figure 2. The proposed on-glass antenna structure

The multi-loop structure provides broad matching characteristics because each loop length is designed to resonate at different frequencies. Design parameters of the proposed antenna are given by the number of loops (N), the length of the outer loop (L_1, L_2, and L_3), and distances between loops (D_1 and D_2). Then, we electrically link each loop using connection lines placed at the four corners. To increase the matching bandwidth and radiation gain, detailed design parameters, such as N, L_1, L_2, L_3, D_1, and D_2 are optimized using a Pareto genetic algorithm (PGA) in conjunction with

FEKO Suite 5.5, EM Software and Systems. The cost functions used in our PGA are shown in (1), (2), and (3).

$$Cost\ 1 = 1 - \frac{BW_{Antenna}}{BW_{FM}} \quad (1)$$

$$Cost\ 2 = \left| \frac{1}{M} \sum_{i=1}^{M} \{Gain(f_i, \theta = 90^\circ, \phi = 270^\circ)\} \right| \quad (2)$$

$$Cost\ 3 = \frac{S_{Antenna}}{S_{Window}} \quad (3)$$

$$30\ MHz \le f_i \le 88\ MHz$$

The design goal can be achieved by minimizing the cost functions. Equation (1) is defined to improve matching characteristics in the FM radio band. $BW_{Antenna}$ is a half power matching bandwidth of the antenna, and BW_{FM} is the FM radio band for aircraft communications (30-88 MHz). To improve the radiation gain of the antenna, equation (2), which means an absolute value of average bore-sight gain in the FM radio band, is added in our cost functions. Equation (3) is used to increase pilots' field of view. $S_{Antenna}$ is the area of the antenna and S_{Window} is the area of the entire window. The optimized antenna occupies an area of 246 m^2, which is 25.7% of the entire glass area (0.331 m^2). Fig. 3 shows the simulated reflection coefficient of the optimized antenna and the result shows a half power matching bandwidth of 17 % (S_{11} < -3dB, 48.3-55.5 MHz, 65.1-69.6 MHz). Fig. 4 is the simulated bore-sight gain, and it shows an average bore-sight gain of -14.1 dBi. We also simulated the azimuth radiation pattern at 60 MHz to examine the omni-directional property of the antenna as shown in fig. 5.

III. CONCLUSIONS

We have investigated the design of aircraft on-glass antennas based on a multi-loop structure that has high radiation gain and broad matching characteristics suitable for use in the aircraft.

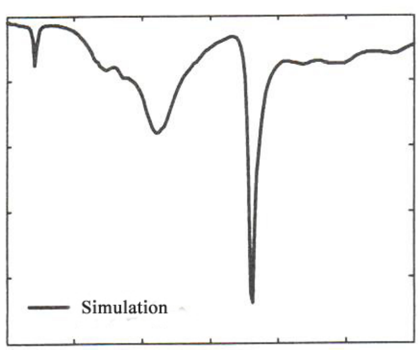

Figure 3. Reflection coefficient of the optimized antenna

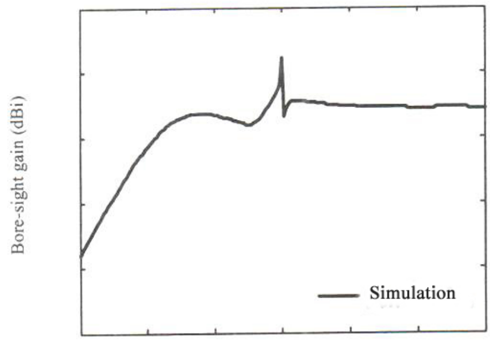

Figure 4. Bore-sight gain of the optimized antenna

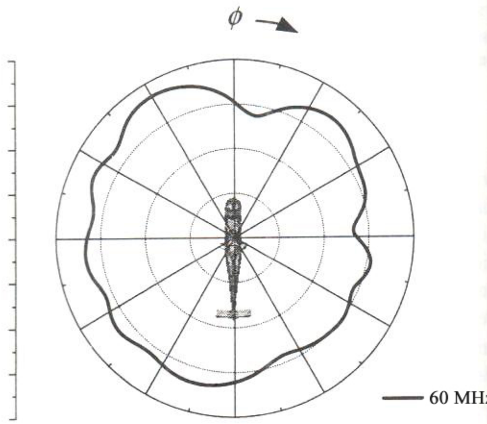

Figure 5. Radiation pattern of the optimized antenna

The optimized on-glass antenna was inserted in KUH-Surion to examine antenna performances. The simulation showed an average bore-sight gain of -14.1 dBi and half power matching bandwidth of 17% in the FM radio band. The field of view of the proposed antenna is 74.3%. The results showed that the proposed antenna is suitable to be used as an aircraft antenna for FM radio communications.

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