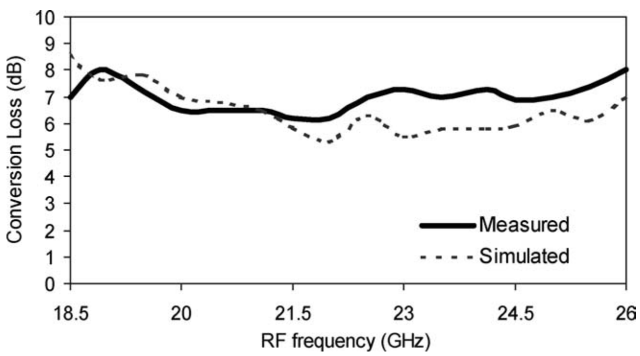

Figure 4 Simulated and measured conversion loss

isolations greater that 35 dB and 49 dB, respectively, have been achieved in simulation. Simulated VSWR at all ports are better than 2.0. The measured conversion loss is 6–8 dB for +10 dBm LO power in whole RF band. The measured LO-IF and LO-RF isolations are greater than 40 dB and 45 dB, respectively. Simulated and measured conversion losses are shown in Figure 4. The agreement of the simulated and measured results is fairly good. Table 2 summarizes the simulated and measured results. The fabricated prototype mixer shown in Figure 5, used for demonstration of the design, was precision machined from aluminum and measures $30 \times 25 \times 22$ mm^3.

5. CONCLUSIONS

A broadband single balanced waveguide mixer at K-band has been developed. The mixer configuration is of crossbar type and is implemented in suspended stripline circuit integrated with RF and LO waveguides. The mixer has wide IF bandwidth with fixed LO frequency. The Mixer has been simulated, fabricated, and measured. Simulation and measured results agrees well. The measured conversion loss across the whole band is 6–8 dB, and LO-IF and LO-RF port isolations are greater than 40 dB and 45 dB, respectively. This mixer design approach can also be applied to design broadband mixer at higher frequency bands. This mixer will be used in broadband communication systems.

TABLE 2 Simulated and Measured Results of Mixer

	Simulated	Measured
Conversion Loss (dB)	5–8	6–8
LO-IF Isolation (dB)	>35	>40
LO-RF Isolation (dB)	>49	>45
RF-IF Isolation (dB)	>30	>28
RF VSWR	<2.0	<2.1

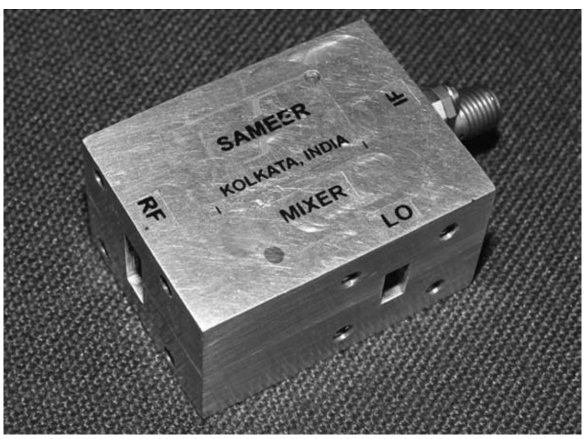

Figure 5 Fabricated prototype mixer

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DESIGN OF AIRCRAFT ON-GLASS ANTENNAS FOR FM RADIO COMMUNICATIONS

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ABSTRACT: *This letter proposes an on-glass antenna for FM radio communications on the aircraft. We apply a multiloop structure to obtain a high-radiation gain with broad matching characteristics. The proposed antenna is designed to imitate the shape of the window frame to minimize disruption to the pilot's visual field. The measurement shows an average bore-sight gain of −13.4 dBi and a half-power matching bandwidth of 52% in the FM radio band.* © 2011 Wiley Periodicals, Inc. Microwave Opt Technol Lett 53:588–590, 2011; View this article at wileyonlinelibrary.com. DOI 10.1002/mop.25779

Key words: *on-glass; antenna; aircraft*

1. INTRODUCTION

Pole-type antennas and blade-type antennas have been widely used for FM radio communications in various types of vehicles. These antennas generally have low durability and high-aerodynamic resistance, because they protrude outside the vehicle. To mitigate these problems, internal on-glass antennas, printed directly onto windows, have been widely developed, especially for use in the auto industry [1–3]. Recently, the aerospace industry has become interested in internal on-glass antennas, due to their durability and aerodynamic advantages. Internal on-glass antennas, however, often have relatively low-radiation gain because the antenna is printed directly onto glass with a high-dielectric constant and loss tangent [4, 5].

In this letter, we propose an on-glass antenna based on a multiloop structure that has high-radiation gain and broad matching characteristics, making it suitable for use in aircraft. Striplines of the multiloop are designed to be placed close to the frame of the window so as to obstruct the pilots' field of view as little as possible. In addition, stripline widths are varied based on current distributions, so as to make the antenna structure visually less obstructive without a significant gain reduction. The designed antenna was built and installed on a Korean military helicopter (KUH-Surion) and performance criteria, such as a matching bandwidth and bore-sight gain, were measured and compared with simulated data from a full-wave EM simulator (FEKO Suite 5.5, EM Software and Systems) [6, 7]. The measured data showed an average bore-sight gain of −13.4 dBi and a half-power matching bandwidth of 52% in the FM radio band (30−88 MHz).

2. ANTENNA STRUCTURE AND CHARACTERISTICS

Figure 1 shows the geometry of the front half of the KUH-Surion. The proposed antenna is located on the left front window, and the feed position is located on the upper side of the window frame that also acts as a ground plane. To estimate accurate antenna performances, the entire geometry is included as 3,300 piecewise triangular meshes into the FEKO software, as shown in Figure 1. An equivalent coated wire method was applied in our EM simulation to increase the simulation speed while maintaining simulation accuracy [8, 9].

Figure 2 shows the proposed antenna structure. The antenna consists of three loops of different lengths, and a feed line. The three loops are designed to imitate the shape of the window frame and are placed on the outer perimeter of the window. This enables the antenna to attain high transparency and to maximize the pilot's field of view. Design parameters of the proposed antenna are indicated 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). The three loops are then linked electrically using connection lines placed at the four corners. The multiloop

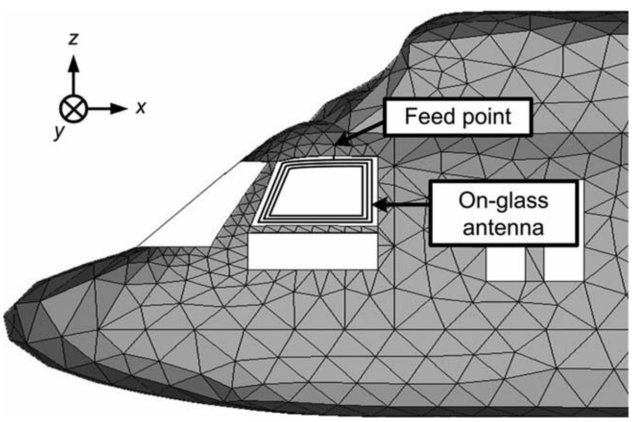

Figure 1 Geometry of Korean Utility Helicopter (KUH-Surion)

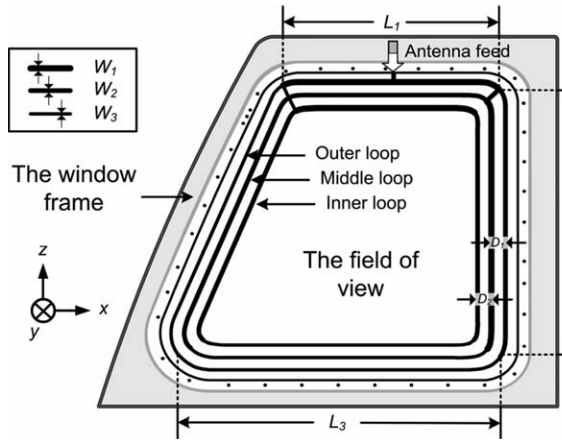

Figure 2 Proposed structure for on-glass antenna

structure provides broad matching characteristics because the length of each loop length is designed to resonate at different frequencies. Generally, loop antennas on a ground plane show a resonance at a frequency where the loop length is approximately half a wavelength. Therefore, we determine the total perimeter of the outer loop, plus the middle loop as about 4.5 m (0.5λ at 35 MHz) to obtain the lowest resonance of 35 MHz. We then make the perimeter of the outer loop as 2.4 m (0.5λ at 60 MHz) for 60-MHz resonance. The perimeter of the inner loop is designed to be 1.9 m to resonate at the frequency of 80 MHz.

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 the EM simulator [10, 11]. The three cost functions in our PGA are defined according to the design goals. The first and second cost functions are included to obtain broad matching characteristics and high bore-sight gain in the FM radio band for aircraft communications (30−88 MHz). In addition, the third cost function is added to increase the pilot's field of view. The optimized design parameters obtained using the PGA are shown as follows: $N = 3$, $L_1 = 565$ mm, $L_2 = 475$ mm, $L_3 = 750$ mm, $D_1 = 20$ mm, $D_2 = 20$ mm, $W_1 = 3$ mm, $W_2 = 2$ mm, and $W_3 = 1$ mm. The field of view of the optimized antenna occupies an area of 246 m^2, which is 74.3% of the entire glass area (0.331 m^2). As the on-glass antenna should allow the pilot's

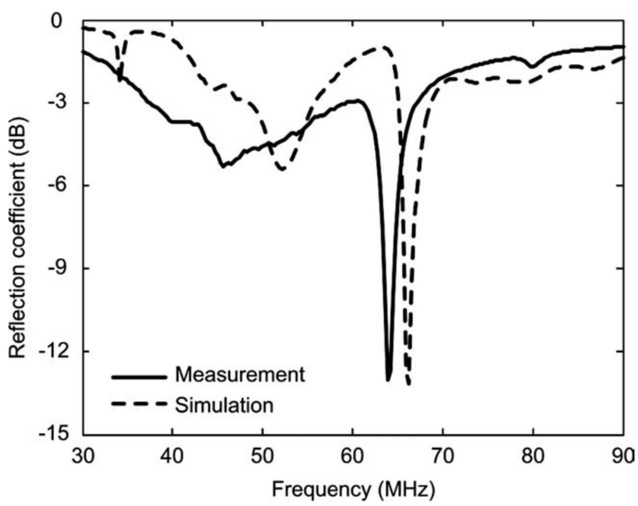

Figure 3 Reflection coefficient of the optimized antenna

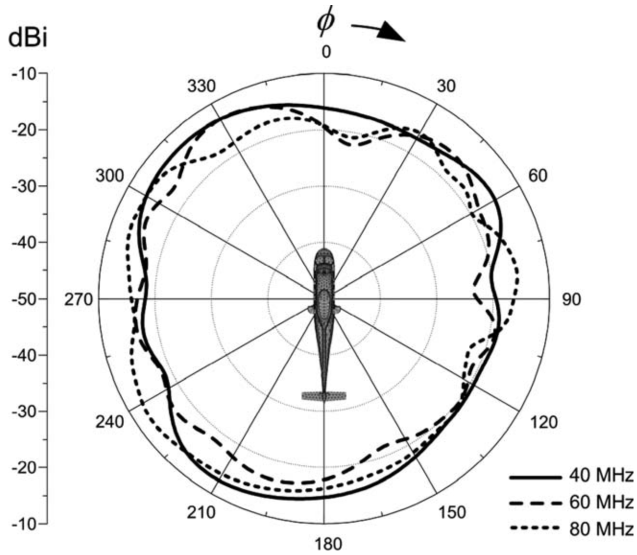

Figure 4 Azimuth pattern of the optimized antenna

view to be as unobstructed as possible, we apply a further design step to improve antenna transparency, based on simulated current distributions. The scheme involves adjusting the widths of striplines, based on current amplitudes. Thus, 1- and 2-mm widths are applied for less than 20 and 30 mA, respectively. This is done to improve the transparency without significantly increasing the conducting loss of striplines.

To verify simulated antenna performances, the optimized antenna is built and installed on a KUH-Surion. Figure 3 shows the simulated and measured reflection coefficient of the optimized antenna. The result shows a half-power matching bandwidth of 52% ($S_{11} < -3$dB, 37.5−67.5 MHz), which agrees well with the simulation result. Figure 4 shows simulated azimuth patterns at 40, 60, and 80 MHz to examine the omnidirectional properties of the antenna. The result shows the azimuth average gain of −16, −18, and −17 dBi at 40, 60, and 80 MHz, respectively. The average gain variation from 30 to 88 MHz is less than 10 dB, which is a good omnidirectional characteristic, considering the dimensions ($15 \times 2 \times 4.5$ m^3) of the KUH-Surion. Figure 5 is the simulated and measured bore-sight gain, and it shows an average bore-sight gain of −14.1 dBi by simulation and −13.4 dBi by measurement.

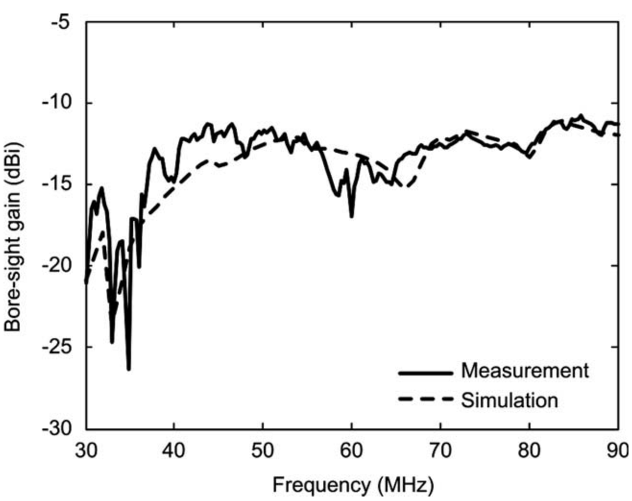

Figure 5 Bore-sight gain of the optimized antenna

3. CONCLUSIONS

We have investigated the design of aircraft on-glass antennas based on a multiloop structure that has high-radiation gain and broad matching characteristics suitable for use in aircraft. The optimized on-glass antenna was built and installed on a KUH-Surion to verify antenna performances. The measurement showed an average bore-sight gain of −13.4 dBi and a half-power matching bandwidth of 52% (37.5−67.5 MHz) in the FM radio band. The field of view of the proposed antenna is 74.3%, and different widths of striplines were applied to improve the transparency of the on-glass antenna. The results showed that the proposed antenna is suitable to be used as an aircraft antenna for FM radio communications.

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ENHANCED GAIN DUAL BAND PATCH ANTENNA BASED ON COMPLEMENTARY RECTANGULAR SPLIT-RING RESONATORS

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ABSTRACT: *A simple and successful dual band patch vertical polarized rectangular antenna design is presented. The dual band antenna is designed etching a complementary rectangular split ring*