REDUCED APERTURE MICROSTRIP ANTENNAS FOR AIRBORNE VEHICLES

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ABSTRACT

The available space for the mounting of antennas on missiles and airborne targets is very limited. The vehicle integrator is constantly striving for smaller antenna apertures while requiring increased performance. Microstrip antennas with moderate dielectric loading have been successfully utilized in the past to meet these requirements. With the advent of high dielectric substrate materials, the designer now has the option of further reducing the size of the antenna while preserving the most desirable performance attributes. An example of the size reduction achievable with the new substrate materials is presented along with performance characteristics.

KEY WORDS

Microstrip, antenna, aperture, substrate, dielectric.

INTRODUCTION

Currently a blade antenna is being used on target drones for Miss Distance Indicator (MDI) applications. It provides omni-directional radiation coverage that is undesirable in some applications. Radar pulses returned from the ocean surface cause the noise floor of the receiver to rise. This increase in the noise floor masks the intended signal rendering the MDI system inoperable. A directional antenna that prevents radiation to the surface will prevent this problem. A circular microstrip antenna was designed for the DSQ-50 program to replace the blade antenna. The microstrip antenna confines the radiation to the upper hemisphere reducing surface reflections. A similar antenna was required for the DSQ-37 program. The frequency of operation is lower however, requiring a larger aperture. It was a requirement that the antenna be enclosed in the same size housing. This paper will discuss a method of reducing the aperture of the DSQ-37 antenna through the utilization of high dielectric substrate materials.

DESIGN CRITERIA

Element Dimension

A half wavelength ($\lambda/2$) circular microstrip antenna was selected for the design. This geometry was selected to meet the aerodynamic requirements of the target drone. The microstrip geometry provides for a very low profile antenna with excellent radiation characteristics. The design equation for the half wavelength circular disk antenna is given below [1]:

$$a = \frac{k}{\left[1 + \frac{2h}{pe_r k}\left\{\ln\left(\frac{pk}{2h}\right) + 1.7726\right\}\right]^{\frac{1}{2}}} \qquad (1\text{-}1)$$

where:

$$k = \frac{8.794}{f_r\sqrt{e_r}}$$

a = element radius (cm)
h = substrate thickness (cm)
e_r = relative dielectric constant of the substrate
f_r = operating frequency (GHz).

A commonly used material for microstrip antennas is RT/Duroid® 5870 (e_r = 2.32). This material has been used extensively in the past for many designs with excellent results. For a given dielectric constant of e_r = 2.32, a substrate thickness (h) of 0.508 cm., and an operating frequency (f_r) of 1.775 GHz, the radius can be shown to be:

a = 3.00 cm.

The radiating aperture of the existing housing is 5.30 cm. A microstrip element designed with the above parameters would be 6.00 cm in diameter, exceeding the aperture size. An antenna with e_r = 2.32 would exceed the aperture size by 0.70 cm.

A decrease in size of the antenna element can be realized by increasing the dielectric constant (e_r) of the substrate as shown in the equation (1-1). A high dielectric material, RT/Duroid® 6006 (e_r = 6.15), was selected to decrease the element size. Using the same design parameters as above, the element radius can be shown to be:

a = 1.96 cm.

This radius results in an element that will fit within the given housing aperture. This diameter microstrip antenna satisfies the requirement to maintain the same size housing.

Bandwidth

An additional consideration for the use of higher dielectric substrate materials is the decrease in bandwidth. For a given frequency and substrate thickness, as e_r increases there is a associated decrease in bandwidth as shown in the following equations [2].

$$BW\% = \frac{s-1}{Q_T\sqrt{s}}\, x\, 100 \tag{1-2}$$

where:

BW = bandwidth
Q_T = total quality factor
s = 2 (for a desired VSWR of 2:1)

$$Q_R = \frac{c\sqrt{e_r}}{4 f_r h} \tag{1-3}$$

where:

Q_R = quality factor associated with radiation resistance
c = speed of light (cm/sec)

for low copper and dielectric losses

$$Q_T \cong Q_R$$

For the e_r = 6.15 material, the bandwidth can be shown to be 3.4%. For the e_r = 2.32 material, the bandwidth is calculated to be 5.6%. It can be seen that there has been a reduction in bandwidth due to the increase in dielectric constant. This is a serious consideration in the use of high dielectric material for wide bandwidth applications.

Design Comparisons

Air(Vacuum) and RT/Duroid® 6010 (e_r = 10.2) were not considered in the original design, but are included in Table 1 for comparison purposes along with the previously considered materials. This table is based on the design parameters: f_r = 1.775 GHz and h = 0.508 cm and is a comparison of the electrical properties for different dielectric materials.

Table 1

	Air	RT/Duroid® 5870	RT/Duroid® 6006	RT/Duroid® 6010
Diel. Const. (e_r)	1.00	2.32	6.15	10.20
Element rad. (a)	4.36 cm	3.00 cm	1.96 cm	1.50 cm
Return Loss*	9.54 dB	9.54 dB	9.54 dB	9.54 dB
% Bandwidth	8.5 %	5.6 %	3.4 %	2.6 %

**This value for return loss is equivalent to a VSWR of 2:1 used in equation (1-2).*

MEASURED RESULTS

An antenna was designed using the RT/Duroid® 6006 (e_r = 6.15) material, along with the design parameters of f_r = 1.775 GHz and h = 0.508 cm. The radius of the circular microstrip antenna was derived in the previous section (a = 1.96 cm). Figure 1 is a plot of the return loss versus frequency for the antenna. From the graph, it can be seen that the bandwidth is 55 MHz. This corresponds to a 3.1% bandwidth. From Table 1, the theoretical bandwidth of 3.4% is in close agreement with the measured result.

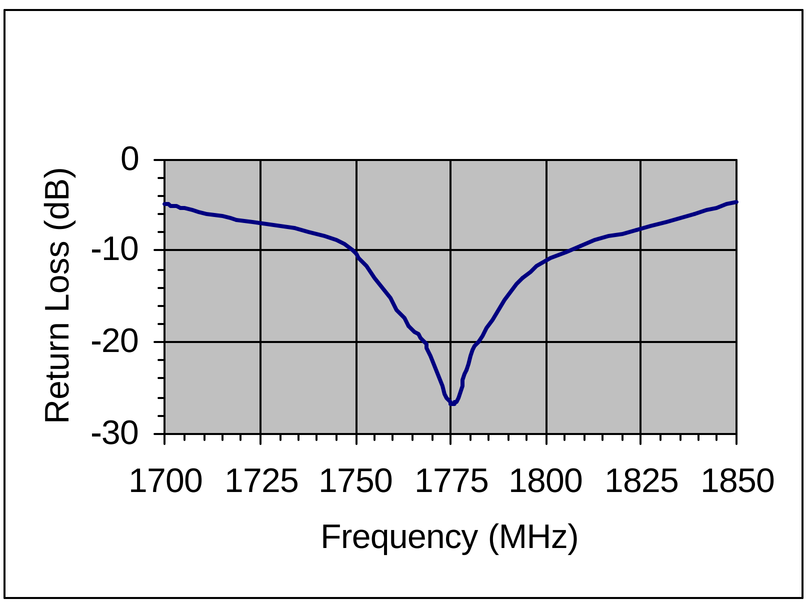

FIGURE 1: ***RETURN LOSS***

The antenna patterns in Figures 2 & 3 are E & H plane radiation plots. The antenna had a maximum gain of 5.6 dBi with very broad coverage, decreasing to a minimum of –6.3 dBi over ±90°.

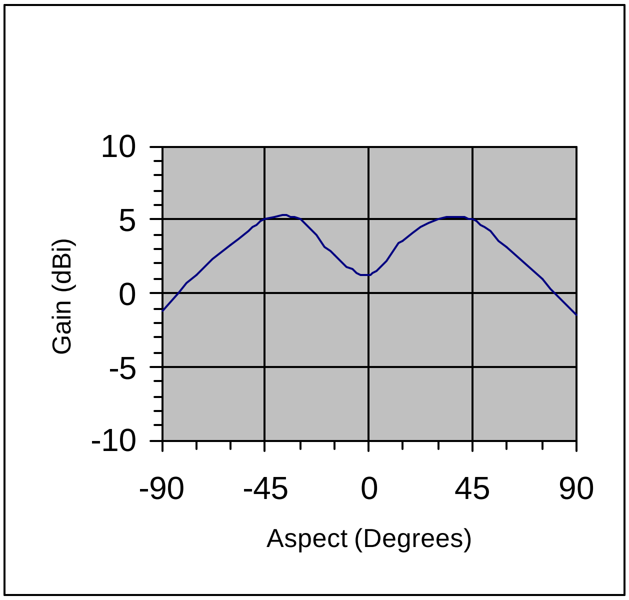

FIGURE 2: *E-PLANE PATTERN*

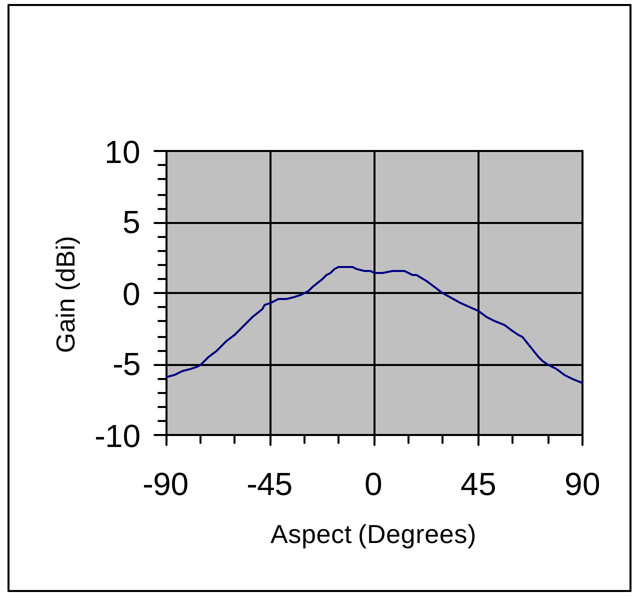

FIGURE 3: *H-PLANE PATTERN*

CONCLUSIONS

The use of high dielectric substrate material to decrease the physical size of an antenna has been discussed. It has been shown that the aperture size for a given frequency can be reduced though the use of high dielectric constant materials. The reduction in aperture size has been found to come at the expense of decreased bandwidth. The other desirable properties of microstrip antennas are maintained, making this a useful alternative for limited aperture size applications. The miniaturization has been a great aid in integrating various antennas onto airborne vehicles.

REFERENCES

[1] Bahl, I.J.; Bhartia, P., "Circular Microstrip Antennas," Microstrip Antennas, Artech House Inc., Dedham, Massachusetts, 1980, Page #119.

[2] ibid, Page #60, #62.

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