MICROSTRIP-FED CYLINDRICAL SLOT ANTENNAS FOR GPS AVIONICS APPLICATIONS

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ABSTRACT

The commercial GPS user antenna for aircraft networks requires a right-hand circular polarization and a uniform pattern coverage over approximately the entire upper hemisphere. It also demands a mechanical configuration that has no appreciable drag and needs no elaborate structural modification to the aircraft. The printed cylindrical slot antennas presented in this paper are useful in this application where low-profile installation is required on a high dynamic aircraft. These new printed GPS antennas provide compact size, low cost, ease of mass production.

I. INTRODUCTION

The evolution of satellite communication networks has proceeded from the design and development stage to actual working systems within the last decade. The Global Positioning System (GPS) is one of the major accomplishments realized in system utilizing satellite communication. GPS system provides accurate three-dimensional position, velocity and precise time traceable to Coordinated Universal Time (UTC). The commercial GPS user equipment for aircraft networks requires an antenna that can provide a right-hand circular polarization and a uniform pattern coverage over approximately the entire upper hemisphere. The uniform amplitude response over a wide coverage region allows the receiver to maintain signal lock to satellites with a useful signal-to-noise ratio. Because a high-speed aircraft constantly changes its look angle to satellites, the wide beamwidth coverage allows the receiver to track as many of the visible satellites as possible and maintain the system's proper Geometric Dilution of Precision (GDOP). Also, a mechanical configuration that has no appreciable drag and requires no elaborate structural modification to the aircraft is another leading concern of airborne terminal in a satellite-to-air communication link. The slot antennas are useful in applications where low-profile or flush installations are required on a high dynamic aircraft.

The slotted cylinder antenna was first introduced by Andrew Alford [1,2] in 1946. The physical structure of the slotted cylinder antenna proposed in [1] consists of a slotted sheet metal bent into a cylinder. He described this type of vertical slotted cylinder as a resonant transmission line with a sufficient number of shunt loops. The antenna radiates a horizontally polarized field with a nearly circular pattern in the horizontal plane. This type of vertical slot antenna is suitable for broadcasting a horizontally polarized wave with a circular pattern in the horizontal plane.

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The radiation properties of microstrip-fed slot antennas were first reported by Yashimura in 1972 [3]. He measured the input impedances and the radiation patterns for various geometries of microstrip-fed slot antennas. The physical structures of these slot antennas are fabricated by simple and conventional photoetching techniques and considered to be suitable in MIC and MMIC transceivers. They also have the advantages of being able to produce bi-directional and unidirectional radiation patterns and requiring very simple feeding and matching techniques. The microstrip conductor crosses the radiating slot and is short-circuited through the dielectric substrate. The slot radiator can be excited either from its center or at a distance from its center. The center-fed slot antenna requires a matching circuit to match the input impedance of the radiating slot to the 50 Ω microstrip feed line. While in offset-fed slot configuration, we can choose the position of microstrip feed line to provide an input match to the characteristic impedance of the line. The microstrip-fed slot antenna can be modeled by a loaded transmission line [4]. The slot antenna is modeled by two short-circuited slot lines loaded with a radiation resistance R_s, representing the radiated power from the slot. The magnetic coupling between the microstrip feed line and slot radiator is modeled by a transformer. The values of turn ratio n and mutual coupling coefficient M are crucial in the determination of the input impedance [4].

To achieve low cost, light weight and small size antennas for commercial GPS aircraft applications, a printed cylindrical slot antennas was developed by using microstrip baluns. This paper a half-wavelength cylindrical slot antenna. The design technique employs four 3/4 turn cylindrical slots etched in the ground plane of four 90° differential-fed microstrip lines. The phase quadrature between the microstrip feed lines excites a circularly polarized wave. Experimental results show that the proposed cylindrical slot antennas have fairly good circular polarization, radiation pattern, and wide beamwidth.

II. HALF-WAVELENGTH CYLINDRICAL SLOT ANTENNA

Figure 1 shows the printed half-wavelength cylindrical slot antenna utilizing microstrip baluns. Each of the slot radiators in Figure 1 is itched in the ground plane of the microstrip feed lines. The microstrip feed line crosses the slot radiator at a right angle and extends about one quarter-wavelength beyond the slot. Unlike the slotted cylinder antenna proposed in [1], each of the four vertical slots in Figure 1 is rolled by 3/4 turn around the cylindrical laminate. This resonant quadrifilar structure [5] is to provide the right-hand circular polarization and increase the radiation coverage in the horizontal plane. At the feed point the center conductor of the microstrip line extends about one quarter-wavelength beyond the slot with an open circuit. This transition causes balanced currents to flow on both sides of the radiating slot and has less effect on the impedance transformation. Therefore, the input impedance of each slot radiator can be matched to a 50 ohm microstrip feed line by a minor adjustment of the length ratio between two short-circuited ends.

The 90-degree phase relationship between the four radiating slots can be achieved by using a microstrip feeding network. The choice of the feeding network can be hybrid types such as the branch line or ratrace coupler, or T-splitters of either matched or unmatched form. Feeds using hybrid couplers and matched T-splitters incorporate a fourth port with an absorbing load.

Figure 2 shows the measured frequency response of input impedance for a microstrip-fed cylindrical slot antenna. The antenna is resonant at 1.5754 GHz with input impedance of 57.4+j7.2 Ω. The return loss at the center frequency is greater than 20 dB. The bandwidth with 10 dB return loss is about 4% of the center frequency. The input impedance was measured at the input terminal of the microstrip feeding network by using an HP8719A vector network analyzer.

Figure 3 shows the radiation pattern of the printed half-wavelength cylindrical slot antenna. As shown in Figure 3, the half power beamwidth is more than 130° and the front-back ratio is more than 20 dB, which is fairly good for the resistance of multipath signals from the ground. The radiation pattern was measured by using an HP8719A vector network analyzer with a calibrated right-hand circularly polarized helical antenna.

A field test for verifying the half-wavelength cylindrical slot antenna was conducted by using a Garmin's GPS90™ receiver. Figure 4 shows the field test results. The test was under a satellite geometry with Position Dilution of Precision (PDOP) of 59 feet. The receiver bar graph shows that satellites 1, 15, 20, 21, and 25 located within the axis angle of $\theta=\pm45°$ have calibrated signal scales of 9, 9, 8, 8, and 9, which corresponds to the receiver phase noise of 51 dB, 51 dB, 49 dB, 49 dB, and 51 dB, respectively. Satellites 5, 14, and 22 located outside the axis angle of $\theta=\pm45°$ have calibrated signal scales of 6, 7, and 8, which corresponds to the receiver phase noise of 45 dB, 47 dB, and 49 dB, respectively. According to the test results, the radiation pattern coverage of the half-wavelength cylindrical slot antenna allows the GPS receiver to track satellites at very low elevation angles.

III. CONCLUSIONS

A new microstrip-fed cylindrical slot antenna was developed and the design procedures were discussed. The experimental results illustrate a fairly good input impedance matching, front-back ratio, and near-hemispherical radiation pattern coverage. With its advantages of low cost, light weight, compact size, and ease of fabrication and assembly, this new printed cylindrical slot antennas are suitable for commercial GPS aircraft applications.

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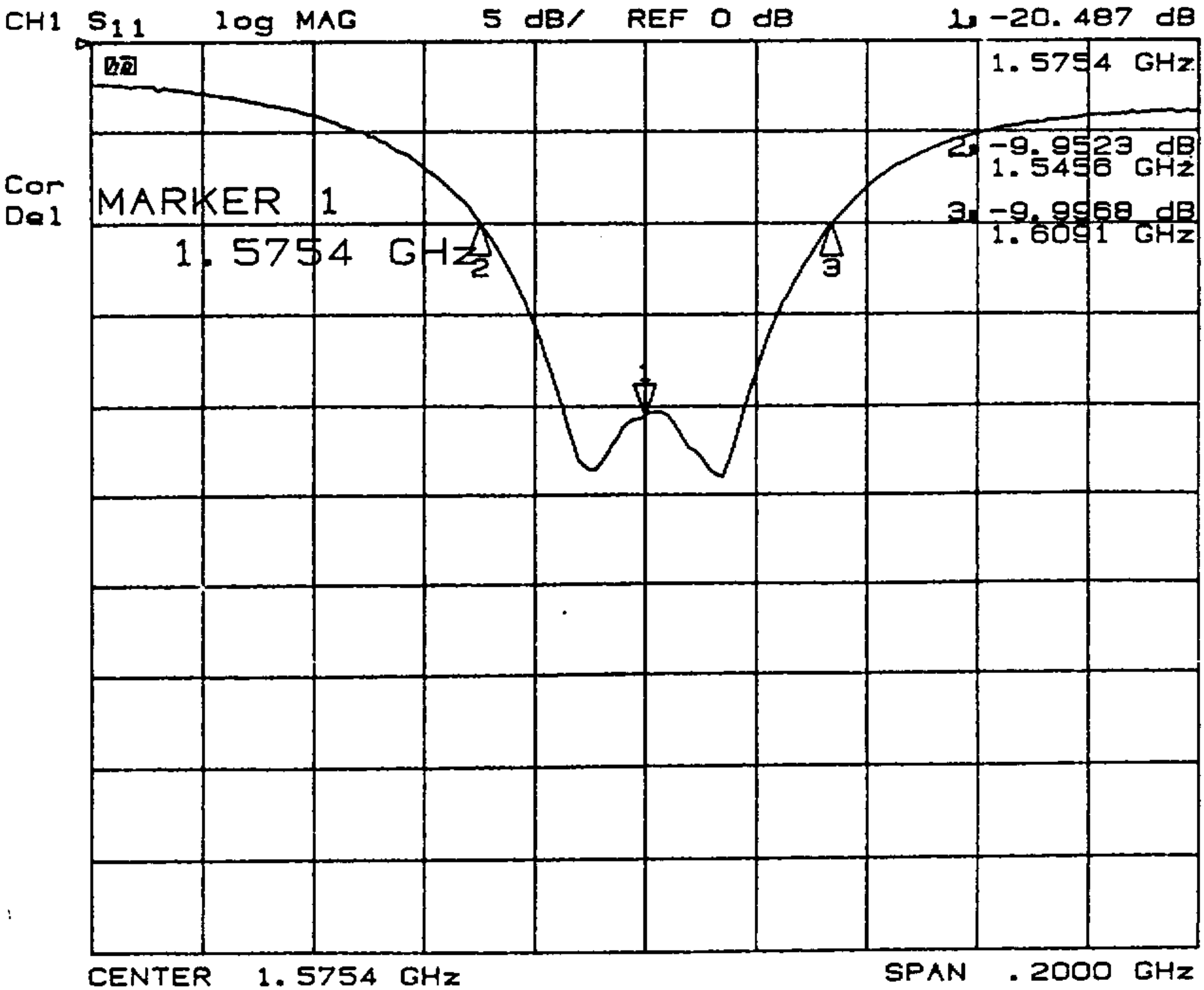
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1.5754 GHz
2: -9.9523 dB
1.5456 GHz
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CENTER 1.5754 GHz
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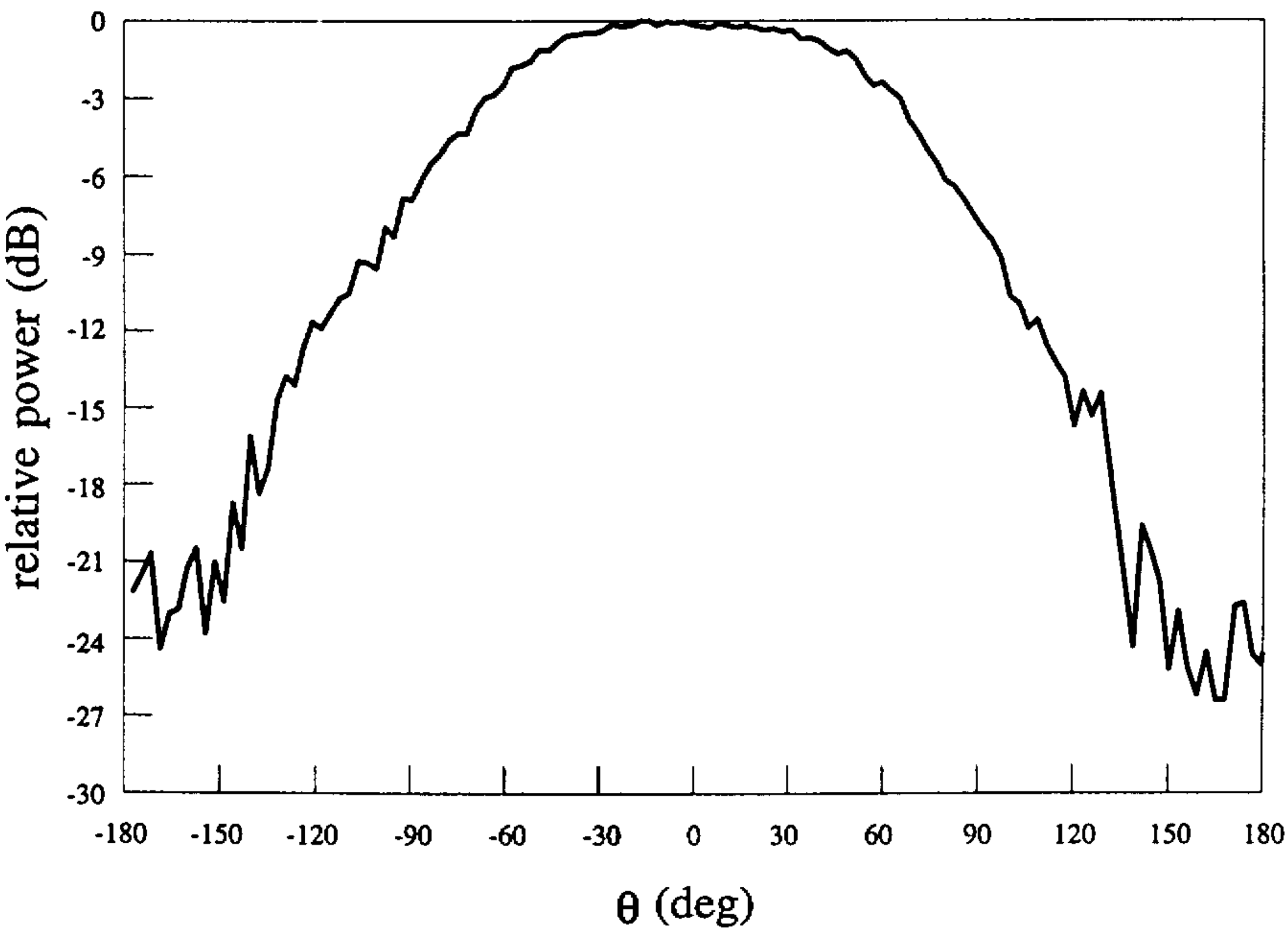
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