Progress In Electromagnetics Research Letters, Vol. 20, 37–44, 2011

A NOVEL PRINTED DIPOLE ANTENNA USING IN HIGH LATITUDES FOR INMARSAT

L. Wang, H. C. Yang, and Y. Li

School of Physical Electronics
UESTC, Chengdu, China

Abstract—A novel printed dipole antenna was designed for the L-band satellite communication system Inmarsat (Downlink: 1525–1559 MHz, Uplink: 1626.5–1660.5 MHz). Several structural parameters were experimentally studied with care to establish a design procedure. The measured results show that the impedance bandwidth for return loss below -10 dB is about 170 MHz and that the half-power bandwidth (HPBW) can be up to 110°. The antenna can be used in high latitudes because of wider HPBW.

1. INTRODUCTION

Nowadays, crew members and passengers expect powerful high speed data and voice connection during their sea voyage. Satellite providers as INMARSAT offer high speed data rate ocean coverage through their L-band satellite system. However, sufficient data rates can only be reached by using medium gain directional tracking antennas. The main receive and transmit frequencies of L-band maritime satellite antenna are 1525 MHz to 1559 MHz and 1626.5 MHz to 1660.5 MHz. In order to transmit and receive with one antenna, the candidate antenna's working frequency should be 1525 MHz to 1660.5 MHz [1–4].

Many antennas have been created through methods and structures. In [5], the antenna consists of a near spherical aperture with 26 radiating elements that allow very good hemispherical coverage and a nearly constant gain down to very low elevation angles. T/R modules were used in the antenna, but because of complex structure and large volume, the antenna would cost too much. Microstrip antenna is always used in INMARSAT because of low profile, light weight and low

Received 10 October 2010, Accepted 26 November 2010, Scheduled 19 January 2011
Corresponding author: Lei Wang (wlay528@163.com).

cost. In [6], the antenna is composed of the combination of different shaped lower and upper antenna elements. In [7], an electronically steerable conformal array antenna was designed and achieved high gain. But those antennas were useless in high latitudes because of the narrow bandwidth characteristics of VSWR and axial ratio. Conformal phase scanned microstrip patch array was design in [8]. 12 elements were used in the array. Though the antenna has a high gain and good elevation pattern in receive band, it still has a narrow pattern in transmit band. A circularly polarized annular-ring slot antenna was designed in [9]. The antenna can be used at 3.5 and 1.59 GHz, and it has a good axial-ratio bandwidth. In order to make the antenna useful in relatively high latitudes, a printed dipole turnstile antenna was designed. The antenna prototype was produced. The measured impedance bandwidth for return loss below −10 dB is about 170 MHz, and the beam width is wider than the common maritime satellite antenna and can be up to 110°.

2. DESIGN AND STRUCTURE

Nowadays, those antennas used for Inmarsat system usually have narrow pattern. A Vee antenna consisting of two printed dipoles was presented in this paper, and the antenna can produce circular polarization field in all directions. The antenna has a wider HPBW than crossed dipole antenna because of vertical current distribution. The length of the dipole is chosen about $0.5\lambda_g$, and it has the same working principle as crossed dipole antenna, so the same analysis method is used [10].

Figure 1 shows the geometry of the antenna. It can be seen from Figure 1(a) that the antenna element is simple and easy to manufacture, and also has good characteristics of circular polarization. The antenna is supported by a FR4 substrate, and the permittivity of the substrate is 4.4. It is found, in the design process, that the permittivity has no significant effect on the antenna performance. The location and size of the patch shown in Figure 1 will affect the resonant frequency of the antenna.

The feeding network of the antenna can be seen in Figure 1(c). The feeding network consists of microstrip structure, and the radius of the circular substrate is 47 mm. The dielectric constant of the FR4 substrate is 4.4 and thickness 1 mm. This feeding network that we used can create circular polarization, for which a 90° phase shift is used. The parameter of l_1 is 2 mm, and l_2 can be calculated from formula $Z = 2^{1/2} Z_0$ which is 1 mm. 50 ohm coax is used to connect the antenna dipoles with the ports of the feeding network just as shown in

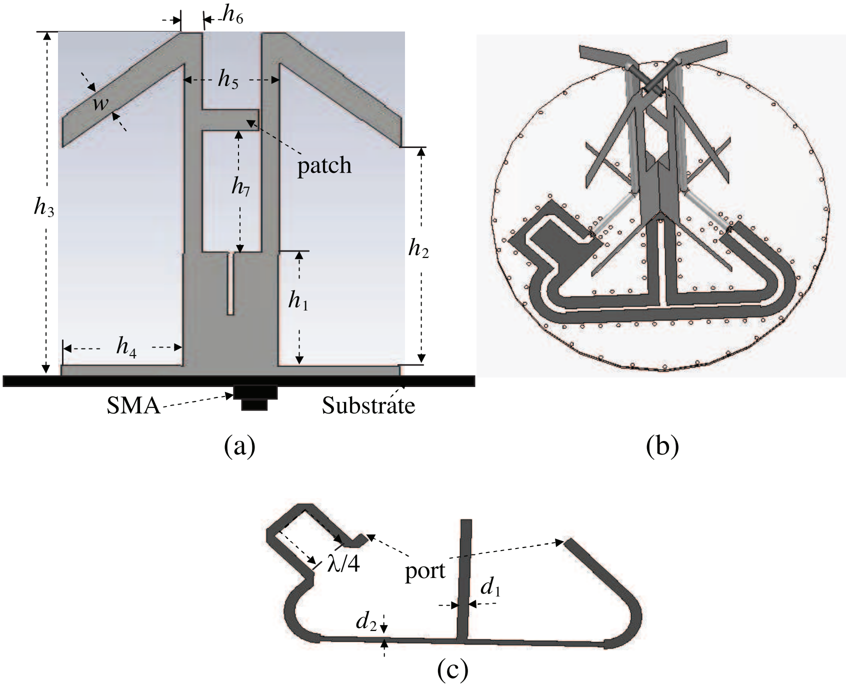

Figure 1. Layout of the proposed printed dipole antenna. (a) Font side of the antenna. (b) 3-D view of the antenna in CST. (c) Feeding network.

Figure 1(b).

For the selected dielectric material, resonant frequency is mostly decided by the length of the antenna arm. The arm width w major decisions dipole input impedance changes with frequency speed. Printed dipole can be equivalent to a cylindrical dipole which radius is $w/4$, so it can also affect the resonant frequency [11–14]. For dipole antenna, in order to create circular polarization field in the axial direction of the antenna, it should have the same feed current amplitude and also a 90° phase shift. Of course, in the other direction are elliptical and linear polarizations.

What affect the antenna pattern is mainly the antenna height and radiation dipole tilt angle, while S-parameters of the antenna was determined mainly by parameters h_3 and w. So the antenna height and tilt angle dipole were adjusted during the design process. During the design, CST-MWS simulation was performed on the proposed structure in order to optimize some important parameters, whose

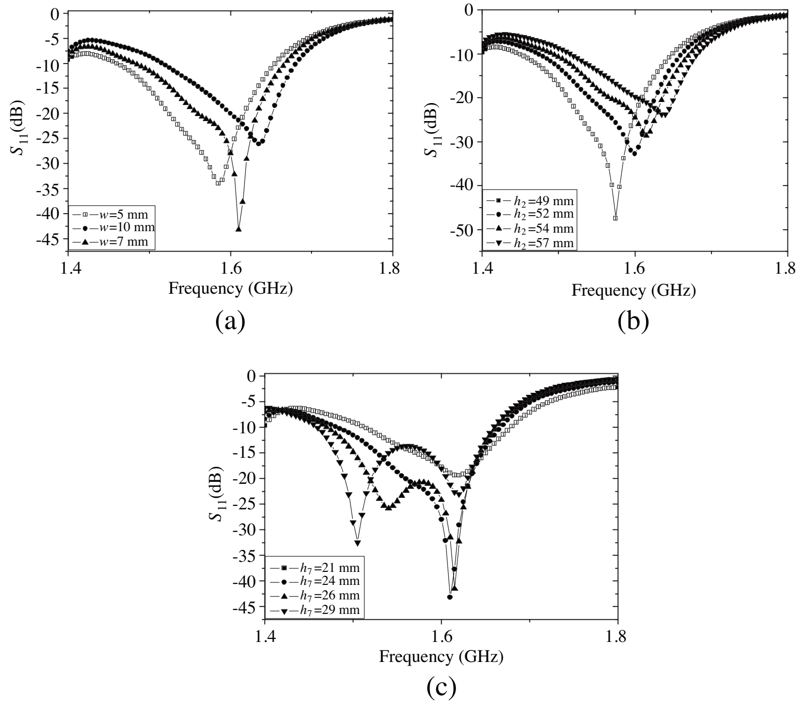

Figure 2. Simulation results with some important parameters. (a) Impact of parameter w changes. (b) Impact of parameter h_2 changes. (c) Impact of parameter h_7 changes.

effects on return loss of the antenna were studied. The variation of parameter w affects the impedance bandwidth and operation frequencies as shown in Figure 2(a). It can be seen from Figure 2(b) that h_2 has an obvious influence on the impedance bandwidth of the antenna. In Figure 2(c), the height of h_7 is varied while other parameters are fixed. It can be seen that the working frequency band moves toward the lower frequency with increasing h_7.

The antenna was fabricated after the main parameters of the antenna were fixed. The photograph of the antenna is shown in Figure 3. Based on the mirror principle, reflecting plate was used in the antenna. It is easily known that the reflecting plate at the bottom of the antenna can increase the gain. The simulated result of the antenna with finite and infinite ground planes is shown in Figure 4. And it is shown that the ground plane has an obvious influence on the gain of the antenna.

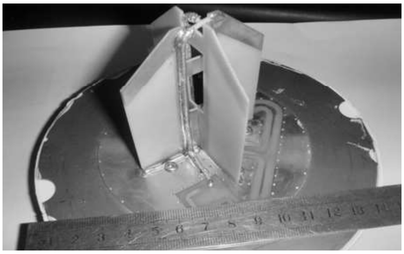

Figure 3. Photograph of the INMARSAT antenna.

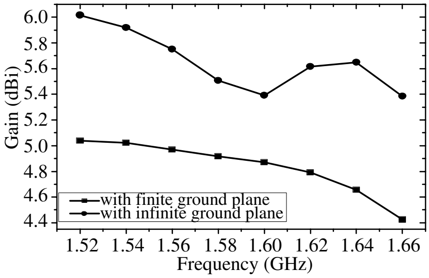

Figure 4. Simulated results comparing the properties of antennas with finite ground plane and with infinite ground plane.

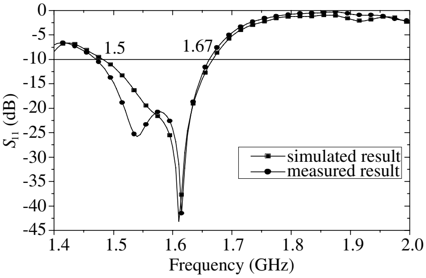

Figure 5. The simulated and measured results of S_{11} for the proposed antenna.

3. RESULT

According to the optimized results using CST MWS, the parameters of the proposed antenna are selected: w=7 mm, h_1=28 mm, h_2=52 mm, h_3=82 mm, h_4=20 mm, h_5=16 mm, h_6=3 mm, h_7=24 mm. Figure 5 displays the simulated and measured results of S_{11}. The results show that the impedance bandwidth for return loss below -10 dB is from 1500 MHz to 1670 MHz and meets the requirement of the INMARSAT system. Generally, the measurement result has a good agreement with the simulated one. Measurement differs from simulation since the SMA connector is not calibrated out and thus adversely affects the S-parameter below 1.6 GHz. The distinctions are contributed mainly by the fabrication inaccuracies, mismatch at the connectors and material losses.

Figure 6 shows the radiation patterns of antenna at 1.525 GHz, 1.545 GHz, 1.64 GHz and 1.66 GHz. The HPBW reaches 100° at 1.525 GHz and wider than 110° at 1.545 GHz, 1.64 GHz and 1.66 GHz.

Also the measured results are in agreement with the simulated ones. In high latitudes, the antennas for INMARSAT system need to provide wide radiation patterns, and this antenna meets the requirement.

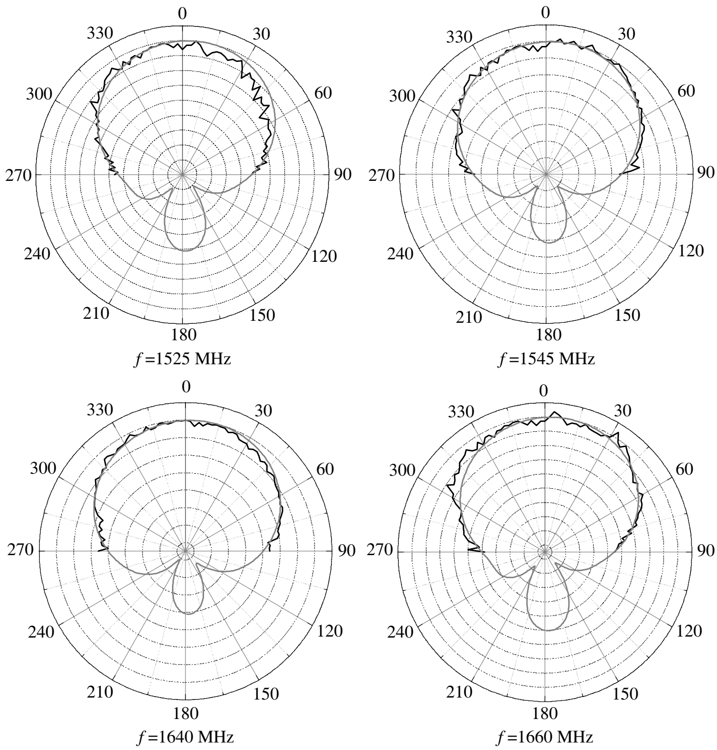

Figure 6. Simulated and measured radiation pattern for the proposed antenna. Black line — measured results. Gray line — simulated results.

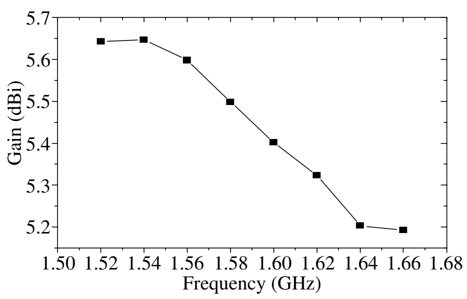

Figure 7. Measured gain of proposed antenna.

The antenna gains are shown in Figure 7. The antenna gain is about 5.65 dBi in lower frequency points and about 5.2 dBi in higher frequency points.

4. CONCLUSIONS

A novel printed dipole antenna for INMARSAT is proposed for its wide HPBW. By adjusting the parameters, the HPBW up to 110° is possible. The simulated results show that the antenna has a good axial ratio performance throughout the pass band. Test results show that this design can basically meet the engineering requirements and can be used in high-latitude regions.

REFERENCES

1. Llcev, S. D., "Inmarsat satellite-based global business solutions for remote and rural communications," *AFRICON 2004, 7th AFRICON Conference in Africa*, 31–37, Sept. 2004.
2. Vladimir, V. S., "Inmarsat systems and services," *ICSC'94, Proceedings of International Conference on Satellite Communications*, 45–52, Oct. 1994.
3. Howell, A. and D. Greenwood, "Antennas for INMARSAT 3 and beyond," *IEE Colloquium on Satellite Antenna Technology in the 21st Century*, 41–46, Jun. 1991.
4. Guy, R. F. E., C. B. Wyllie and J. R. Brain, "Synthesis of the INMARSAT 4 multibeam mobile antenna," *12th International Conference on Antennas and Propagation*, 90–93, Mar. 31–Apr. 3, 2003.
5. Geissler, M., F. Woetzel, M. Bottcher, S. Korthoff, A. Lauer, M. Eube, and R. Gieron, "Innovative phased array antenna for maritime satellite communications," *EuCAP2009, 3rd European Conferenc on Antennas and Propagation*, 735–739, Mar. 23–27, 2009.
6. Pivit, F., D. Loffler, and W. Wiesbeck, "A broadband, ship based, electronically steered L-band SATCOM antenna," *IEEE Antennas and Propagation Society International Symposium*, 456–459, Jun. 2003.
7. Noro, T. and Y. Kazama, "A novel wideband circular polarization microstrip antenna combination of different shaped antenna element," *IEEE Antennas and Propagation Society International Symposium*, 467–470, Jul. 2005.

8. Strickland, P. C., "Planar arrays for MSAT and INMARSAT land mobile satellite communications," *Antennas and Propagation Society International Symposium*, Vol. 3, 1388–1391, Jun. 18–23, 1995.
9. Sze, J.-Y., C.-L. G. Hsu, M.-H. Ho, Y.-H. Ou, and M.-T. Wu, "Design of circularly polarized annular-ring slot antennas fed by a double-bent microstripline," *IEEE Transactions on Antennas and Propagation*, Vol. 55, No. 2, 3134-3139, Nov. 2007.
10. Lin, C. L. , *Circularly Polarized Antenna*, Post & Telecom Press, Peking, China, 1986.
11. Bao, X. L. and M. J. Ammann, "A printed dipole antenna for wideband circular polarization operation," *EuCAP2009, 3rd European Conference on Antennas and Propagation*, 2367–2370, Mar. 2009.
12. Fan, Z., S. Qiao, H.-F. Jiang Tao, and L. X. Ran, "A miniaturized printed dipole antenna with v-shaped ground for 2.45 GHZ RFID readers," *Progress In Electromagnetics Research*, Vol. 71, 149–158, 2007.
13. Lumini, F. and J. C. da S. Lacava, "Near electromagnetic fields in open chirostrip structures excited by printed dipoles," *Progress In Electromagnetics Research*, Vol. 27, 61–89, 2000.
14. Hu, Y.-S., M. Li, G.-P. Gao, J.-S. Zhang, and M.-K. Yang, "A double-printed trapezoidal patch dipole antenna for UWB applications with band-notched characteristic," *Progress In Electromagnetics Research*, Vol. 103, 259–269, 2010.