Hindawi Publishing Corporation
International Journal of Antennas and Propagation
Volume 2009, Article ID 836074, 5 pages
doi:10.1155/2009/836074

Application Article

Flat Array Antennas for Ku-Band Mobile Satellite Terminals

Roberto Vincenti Gatti, Luca Marcaccioli, Elisa Sbarra, and Roberto Sorrentino

RF Microtech srl, a spin-off of the University of Perugia c/o DIEI, via G. Duranti 93, 06125 Perugia, Italy

Correspondence should be addressed to Roberto Vincenti Gatti, vincenti@rfmicrotech.com

Received 30 September 2008; Revised 9 January 2009; Accepted 17 February 2009

Recommended by Stefano Selleri

This work presents the advances in the development of two innovative flat array antennas for Ku-band mobile satellite terminals. The first antenna is specifically conceived for double-deck trains to allow a bi-directional high data rate satellite link. The available circular surface (diameter 80 cm) integrates both a transmitting and a receiving section, operating in orthogonal linear polarizations. The TX frequency range is fully covered while the RX bandwidth is around 1 GHz arbitrarily allocated on the DVB range depending on requirements. The beam is steered in elevation through a phased array architecture not employing costly phase shifters, while the steering in azimuth is mechanical. Active BFNs allow excellent performance in terms of EIRP and G/T, maintaining extremely low profile. High antenna efficiency and low fabrication cost are ensured by the employment of innovative SIW (Substrate Integrated Waveguide) structures. The second antenna, receiving-only, is designed for radio/video streaming services in mobile environment. Full DVB coverage is achieved thanks to cavity-backed patches operating in double linear polarization. Two independent broadband active BFNs allow simultaneous reception of both polarizations with full tracking capabilities and a squintless beam steering from 20° to 60° in elevation. A minimum gain of 20 dBi and $G/T > -3\,\mathrm{dB}/^\circ\mathrm{K}$ are achieved, while maintaining extremely compact size and flat profile. In the design of both antennas fabrication cost is considered as a driving factor, yet providing high performance with a flat profile and thus resulting in a great commercial potentiality.

1. Introduction

In the last few years an increasing interest has been addressed to many satellite services at Ku-band being proposed or already operative, ranging from digital radio and TV broadcast to broadband internet services. Potential applications and markets especially regard mobile environments (cars, trains, boats, airplanes), though some particular applications may also involve fixed users (e.g., flat wall-mounted antennas for digital TV and radio for environmental impact reduction).

The success of new services and the expansion of those already present depend to a great extent on the user terminal costs and performance and therefore on the employed antenna, which becomes a critical component of the whole system. Since most of the applications refer to mass consumer markets, the first driving factor for the antenna design and development is the fabrication cost, that must be maintained as low as possible. A compact size is then needed for an easy placement on mobile vehicles, and for many applications a flat profile is mandatory to maintain aerodynamic properties of the vehicle as well as to allow the integration of the antenna itself. Finally high performance must be achieved in terms of EIRP and G/T in such a way as to ensure high data bit rate links, as well as the automatic beam steering to maintain the link in mobile environment. The most critical issue for an effective design achieving such stringent requirements is indeed the identification of the most suitable technology. The development of high-performance and low-cost critical components (e.g., LNA's, rotary joint, radiating element, etc.) is furthermore essential as well as the implementation of a cost-effective architecture for the BFN and control system. The major limiting factor for mobile terminal development is indeed represented by the beam steering approach and the number of electronic components employed. To that end RF Microtech has recently proposed [1] an alternative approach for beam steering, not employing phase shifters, based on a switched beam architecture to obtain electronic beam steering in the elevation plane, while mechanical

(a)

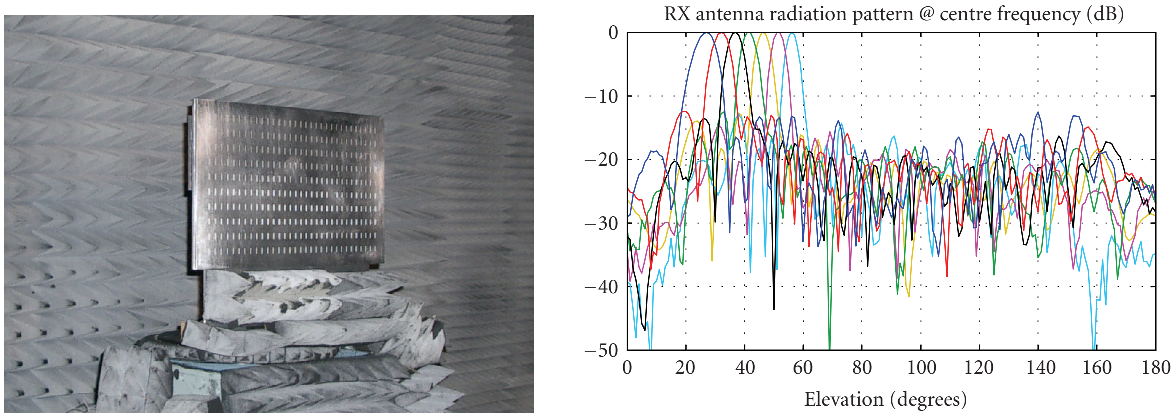
(b)

Figure 1: Typical scenarios of applications: (a) mobile vehicles such as cars, trains, boats, and trains; (b) example of strong environmental impact that could be reduced with the employment of flat wall-mounted antennas for DVB and radio reception.

beam steering is performed in the azimuthal plane. This approach allows a considerable reduction of the overall system complexity and fabrication costs being the BFN realized in microstrip technology in the form of a Rotman lens, still maintaining extremely high performance through the use of LNAs. The use of COTS in this case is the most convenient solution due to the extremely wide market of such components, already employed in all standard DVB receivers (LNB's for reflector antennas), making the cost of a single LNA as low as 2 €. None of the solutions present on the market or under development seem to retain all the required features, being either too costly or too bulky especially for what concerns the profile. In this work two innovative antenna systems for mobile satellite terminals at Ku-band are presented, retaining all the above mentioned characteristics. The constituting elements of such antennas will be described in detail, and the achievable performance as well as the great potential of the proposed solutions will be illustrated.

2. Electronic Beam Scanning RX/TX Flat Antenna

The first antenna is specifically conceived for double-deck trains to allow a bidirectional high data rate satellite link, though with proper adjustments it could be also employed also in other kind of vehicles. The first and most important specification to be satisfied is the flat profile (<5 cm), together with a limited area (<80 cm) compliant with the roof of a double-deck train. The research group at the University of Perugia headed by professor Roberto Sorrentino is active in the field of flat beam scanning antennas since 2000.



(a) (b)

Figure 2: SAET RX prototype antenna, 32×10 slotted waveguide array: (a) measurement setup; (b) measured radiation patterns.

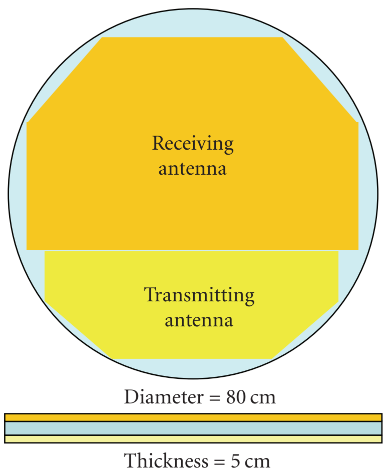


Figure 3: Final version size and geometry.

Table 1: Expected RX/TX antenna performance.

Parameter	Unit	TX section	RX section
Centre frequency	GHz	14.125	11.575
Bandwidth at VSWR<1.5	MHz	800	800
Polarization	—	Linear H	Linear V
Min gain (at 25° elev.)	dBi	31.2	31.8
Side lobe level	dB	−12	−12
Cross polarization	dB	−25	−25
Scan angles (elevation)	Degree	25° ÷ 50°	25° ÷ 50°
Scan angles (azimuth)	Degree	360°	360°
EIRP (ITU-R S.728.1)	dBW	32	—
G/T (at 25° elev)	dB/°k	—	10
Size (D×H)	Cm	80 × 5	

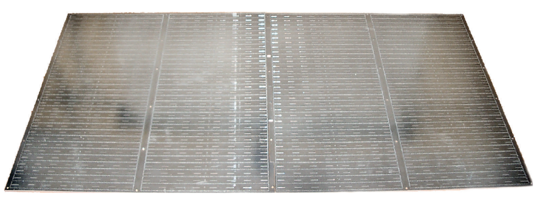
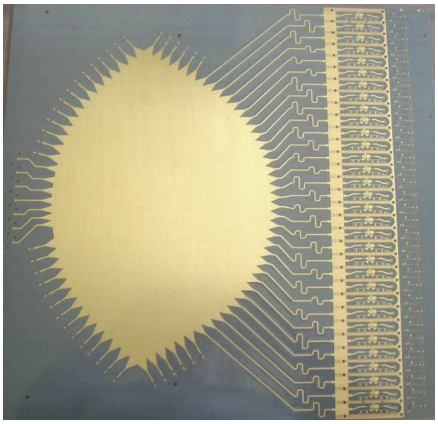


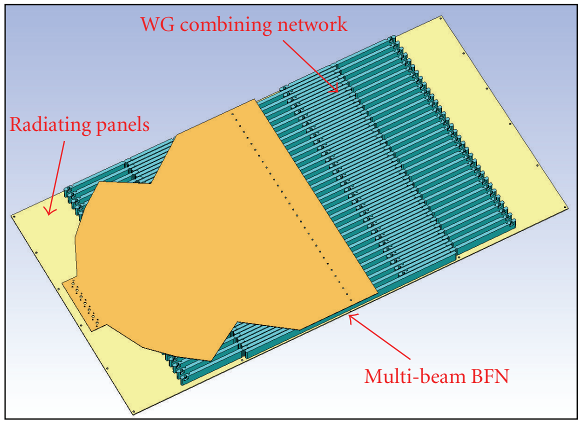
Figure 4: RX panel realized in SIW technology. The array is made of 32×32 slots, with a size of approximately 40×80 cm.

Figure 5: Fabricated waveguide combining network.

This research activity has produced along the years a number of interesting and innovative solutions for mobile satellite terminal antennas operating up to Ka-band [2–7] and has spurred the development of a unique cad tool for the design of slotted waveguide technology [8]. In 2005 the University of Perugia was involved in ESA Project “Satellite Access for European Trains” (SAET, Contract N° 14272/00/NL/US) for a feasibility study of a bidirectional high-performance Ku-band flat antenna for mobile terminals to be placed on the roof of double deck trains [9]. In this framework the maximum achievable performance was assessed, and slotted waveguide technology was identified as the most suitable technology for the realization of the flat array antenna. This result has been supported by the design, fabrication, and test of a proof-of-concept slotted waveguide array antenna. The tests have confirmed the validity of the electromagnetic modelling and the design tools as well as the feasibility of the proposed solution. The proof-of-concept antenna is represented by a dielectric-filled slotted waveguide array made of 32 waveguides with 10 slots each, and it is realized in aluminium. It has been designed and optimized to present the best performance in the scanning range from 30° to

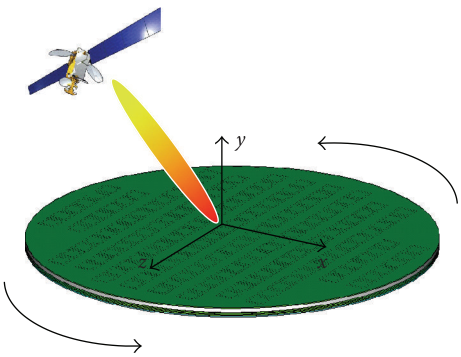


(a)

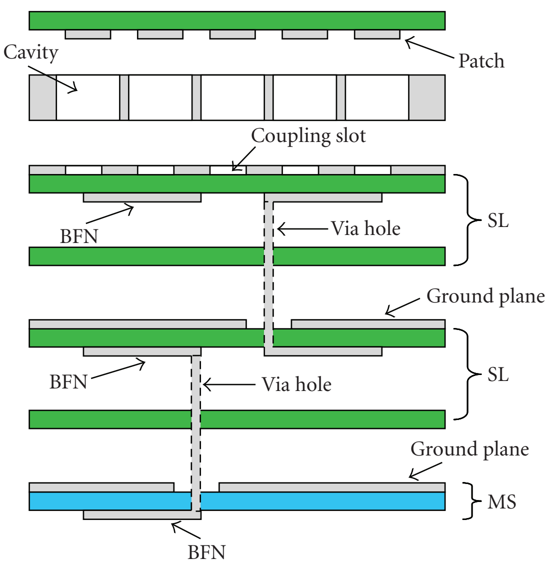


(b)

Figure 6: Fabricated active Rotman lens (a); schematic 3D view of the final antenna (b).



(a)



(b)

Figure 7: Antenna Architecture. BFN realized with two stripline layers and a microstrip layer. Beam scanning is electronic in elevation and mechanical in azimuth.

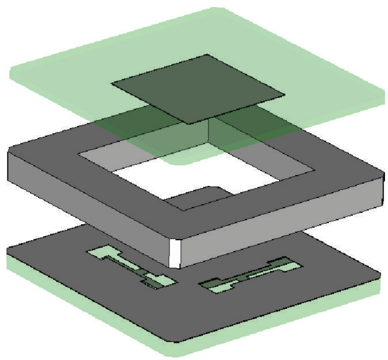


Figure 8: Dual polarization radiating element.

50° in elevation (E-plane). Measured results confirm the high performance achievable with this technology, giving an overall antenna efficiency of about 80%.

With the conclusion of SAET Project, a self-financed R&D activity has been carried out aimed at the development of a ready-to-market product. To that purpose the spin-off company RF Microtech has been founded in 2007. What follows is the result of this activity. Table 1 shows the expected performance for the final antenna.

The final shape of the antenna will be circular (diameter 80 cm), as shown in Figure 3. A prototype antenna with the same performance of the final version but with a rectangular shape is now under construction. A picture of the RX panel is shown in Figure 4. The prototype antenna consists of two radiating panels for reception and transmission, respectively, each subdivided in four sections made of 32 centre-fed slotted waveguides with 8 slots each. Longitudinal slots are used for the receiving section while transverse slots are employed for the transmitting antenna. Substrate integrated waveguide (SIW) technology is employed, with strong impact on cost, ease of fabrication, thickness, and weight. Subarrays of the same line are fed in phase through the lowloss waveguide BFN shown in Figure 5, connected to a 32-way active Rotman lens realized in printed technology (see Figure 6) for

Table 2: Expected antenna performance.

Operative Frequency	10.7 ÷ 12.75 GHz
Polarization	Dual linear V/H
Scanning angle	Elevation: 20° ÷ 60° Azimuth: 0° ÷ 360°
3 dB beamwidth	>6° in azimuth >10° in elevation
Gain	>20 dBi
G/T	> −2 dB/°k
Thickness	<1 cm
Size	<30 cm
Estimated price (min 10.000 units)	<500 €

beam steering in elevation, while mechanical beam steering is performed in the azimuthal plane. The overall thickness is around 3 cm and total weight <20 kg. 12 dB-gain and 1 dB-NF LNAs covering the full DVB frequency range have been integrated in the RX section, while low-cost monolithic PA's are integrated in the TX printed circuit. The use of active BFNs allows high antenna efficiency and therefore high performance with a compact size and a low cost. Experimental results of the complete prototype are expected in the next few months.

3. Receiving-Only Broadband Dual Polarization Flat Antenna

The second antenna under development is a receiving-only circular array with full DVB frequency range coverage (10.7÷12.75 GHz) with simultaneous dual polarization. Main features are summarized in Table 2.

The antenna is fully realized in printed technology, the radiating element being a cavity-backed slot-fed patch antenna. Two parallel broad-band BFNs are employed, one for each polarization, realized with two strip-line layers and a microstrip layer where an active BFN, integrating LNAs at subarray level, is realized to allow electronic beam steering in the elevation plane. The overall architecture and the radiating element are shown in Figures 7 and 8. Full polarization tracking is possible, since the two orthogonal linear polarizations (V and H) are available at the same time. For the same reason a simultaneous double circular polarization is also possible (LHCP and RHCP) using simple passive circuitry. Two antennas with different diameters (22 cm and 30 cm) have been designed, employing 144 and 296 elements, respectively. The overall thickness is <1 cm. Beam steering is performed without the use of phase shifters and extremely low-cost active components are employed for the LNAs, thus resulting in a very competitive solution, potentially applicable also for larger diameters. The adopted beam steering architecture, together with the full DVB coverage, the simultaneous double polarization, and the low fabrication costs makes the proposed antenna system an attractive solution also as a flat wall-mount panel for fixed satellite terminals.

4. Conclusions

In this work two innovative products under development at RF Microtech have been presented. The proposed antenna systems include unique features which ensure a flat profile, reconfigurability, and high performance at a low cost. Prototypes of both solutions will be available for testing in the next few months.

Acknowledgments

The project of the receiving-only broadband dual-polarization flat antenna has been developed in the framework of two thesis works. The authors would like to thank Sonia Calzuola and Elisa Chiuppesi for their contribution.

References

[1] R. Vincenti Gatti, L. Marcaccioli, E. Sbarra, and R. Sorrentino, "Flat array antennas for Ku-band mobile satellite terminals," in *Proceedings of the 30th ESA Antenna Workshop on Antennas for Earth Observation, Science, Telecommunications and Navigation Space Missions*, pp. 534–537, Noordwijk, The Netherlands, May 2008.

[2] R. Vincenti Gatti, R. Sorrentino, and M. Dionigi, "Equivalent circuit of radiating longitudinal slots in dielectric filled rectangular waveguides obtained with FDTD method," in *Proceedings of IEEE MTT-S International Microwave Symposium Digest (MWSYM '02)*, vol. 2, pp. 871–874, Seattle, Wash, USA, June 2002.

[3] R. Vincenti Gatti and R. Sorrentino, "A Ka-band active scanning array for mobile satellite terminals using slotted waveguide technology," in *Proceedings of the 25th ESA Antenna Workshop on Satellite Antenna Technology (ESTEC '02)*, Noordwijk, The Netherlands, September 2002.

[4] R. Vincenti Gatti, R. Sorrentino, and M. Dionigi, "Fast and accurate analysis of scanning slotted waveguide arrays," in *Proceedings of the 32nd European Microwave Conference (EuMC '02)*, pp. 1–4, Milan, Italy, September 2002.

[5] R. Vincenti Gatti and R. Sorrentino, "Low-cost flat-profile active scanning antenna for mobile satellite terminals in Ka-band," in *Proceedings of the 3rd ESA Workshop on Millimetre Wave Technology and Applications*, pp. 61–68, Espoo, Finland, May 2003.

[6] R. Vincenti Gatti, L. Marcaccioli, and R. Sorrentino, "Design of slotted waveguide arrays with arbitrary complex slot voltage distribution," in *Proceedings of IEEE International Symposium on Antennas and Propagation Society (APS '04)*, vol. 3, pp. 3265–3268, Monterey, Calif, USA, June 2004.

[7] R. Vincenti Gatti and R. Sorrentino, "A fast and accurate CAD tool for slotted waveguide arrays for radar applications," in *Proceedings of the 1st European Radar Conference (EuRAD '04)*, pp. 181–184, Amsterdam, The Netherlands, October 2004.

[8] SWAN, http://www.swan-soft.com/.

[9] R. Vincenti Gatti, R. Sorrentino, V. Schena, and G. Losquadro, "Flat-profile active scanning antenna for satellite terminals in Ku-band operating on new fast trains generation," in *Proceedings of the 28th ESA Antenna Workshop on Satellite Antenna Technology (ESTEC '05)*, Noordwijk, The Netherlands, May-June 2005.