A FIVE-BAND ANTENNA FOR TERRESTRIAL AND SATELLITE RADIO SERVICES

S. Lindenmeier[1], G.R. Olbrich[2], J.F. Luy[1], P. Russer[2]

[1]DaimlerChrysler Research and Technology, Ulm, Germany
stefan.lindenmeier@daimlerchrysler.com, johann-friedrich.luy@daimlerchrysler.com
[2]Lehrstuhl fuer Hochfrequenztechnik, Technische Universitaet Muenchen, Muenchen, Germany
olbrich@ei.tum.de, russer@ei.tum.de

ABSTRACT

A five band antenna for the terrestrial radio services GSM (900MHz) and UMTS (2000MHz) as well as for the satellite radio services Globalstar (1616MHz and 2.5GHz) and GPS (1575MHz) is developed, realized and tested. The radiation characteristic of the antenna is horizontally omni-directional for vertically polarized waves at the frequency bands of the terrestrial services GSM and UMTS and exhibits a circularly polarized vertical main lobe at the frequency bands of the satellite radio services GPS and Globalstar. The five-band antenna consists of four triangular monopole antenna elements in a horizontal plane. A first demonstrator has been fabricated. Measurement results will be presented.

INTRODUCTION

Multiband antennas can be used simultaneously for two or more radio services [1-5]. The combination of terrestrial radio services and satellite services in one antenna has been introduced for up to three services [6,7]. In this paper we present a five band antenna for the combination of terrestrial and satellite radio services. It can be applied to the frequency bands GSM, UMTS, GPS, Globalstar 1.62GHz and Globalstar 2.5GHz. This bidirectional antenna can be used for the transmission and reception of a variety of terrestrial and satellite radio services at once and is not restricted to specific radio services. The antenna can be adjusted without a high development effort to other radio services by redesign of the feeding circuitry. Work is in progress to extend the applicability of the antenna also to the service "Sirius". While for the terrestrial radio services GSM or UMTS the antenna transmits and receives vertically polarized waves omnidirectionally within the horizontal plane the same antenna transmits and receives circularly polarized waves with a vertical main lobe at the frequencies of the satellite radio services GPS and Globalstar.

THE FIVE-BAND ANTENNA

The five-band antenna is an array of four antenna elements each given by a triangular monopole structure in a horizontal plane. A first demonstrator of the complete five-band antenna structure with four matching circuits and a power divider and phase shifting circuit has been fabricated and measured. The demonstrator is shown in top view in Fig. 1 and in bottom view in Fig. 2.

Fig. 1 Top view of the five-band antenna structure

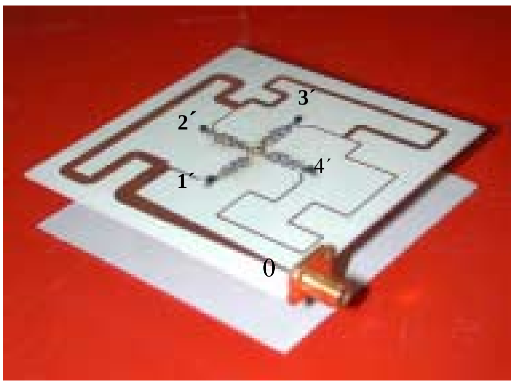


Fig. 2 Bottom view of the five-band antenna with phase shifting and matching circuit

The phase shifting circuit yields a frequency dependent individual phase at each of the four antenna elements in such a way that for all the terrestrial services the antenna elements are in phase so that the antenna elements together represent one monopole antenna for vertically polarized waves. For all the satellite services there is a phase shift of 90° between neighboring antenna elements in a way that the triangular horizontal structures together form a crossed dipole structure for circular polarized waves. The monopole antenna elements are connected each via a matching two port circuit to the ports 1', 2', 3' and 4' at the opposite side of the ground plane (Fig. 2), in order to obtain a matching to 50Ω.

For the design of the matching circuits the scattering parameters of the four antenna elements are measured. From the four port S-matrix of the four antenna elements the input impedances of the antenna elements are calculated for the center frequencies of the considered radio services at 900 MHz, 1575 MHz, 1616 MHz, 2000 MHz and 2500MHz. Based on these parameters the matching circuit at the required center frequencies are designed as described in [7]. Starting from a lossless structure of the matching circuit, we design the non-ideal circuit considering losses and the geometrical structure of the elements. The parameters of the circuit elements are then optimized in order to obtain optimal matching. The matching circuit is designed using SMD-components on ceramic substrates (ε_r=10.8) in microstrip technique. For the design of the matching circuits we start an optimization based on a circuit of fourteen elements which leads to ideal matching at the center frequencies of the considered radio services if we consider ideal lossless elements. Since we have to consider tolerances and losses of real circuit elements and in order to save space on the substrate we want to reduce the number of circuit elements as much as possible. Realization was done after an optimization process with matching circuits each consisting of eight lumped elements.

In order to obtain a frequency dependent phase at the antenna elements the phase shift and power divider circuit connects the ports 1' ,2', 3' and 4' with the external port 0 (Fig. 2 and 3). The external port of the antenna can be used bidirectional for transmission and reception of all the services. The phase shift/power divider circuit is realized as a microstrip structure with delay lines. The antennas are positioned at the opposite side of the ground plane in order to have a minimum coupling between the antennas and the phase shift and matching circuits. At each of the ports 1′, 2′, 3′ and 4′, one quarter of the total power at port 0 is transmitted.

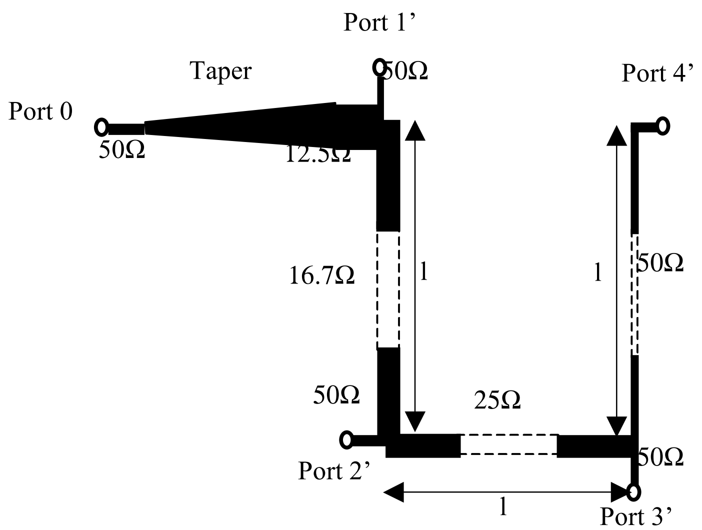


Fig. 3 Scheme of the phase shift circuit with power divider for the four antenna elements

The required phase shift between the antenna elements is achieved via different line lengths between port 0 and the antenna ports 1', 2', 3' and 4'. At the frequencies of the satellite bands we obtain a phase difference of approximately 90° between the ports 1′, 2′, 3′ and 4′. For the frequencies of the terrestrial bands there is no phase difference between all the ports, all antenna elements are feeded cophasal. If we choose a substrate with ε_r=10.8 for the circuit the losses are lower than 0.5dB. In order to save space on the substrate we realize the transmission lines in meander form.

RESULTS

The receiving of terrestrial services via the five-band antenna is measured as required in the horizontal plane of the antenna using a wide band logarithmic periodic antenna for reception with vertical polarisation. The transmission of satellite services is measured, in the vertical direction to the plane of the five-band antenna. Since the five-band antenna is a bidirectional passive structure the transmission represents also its receiving properties.

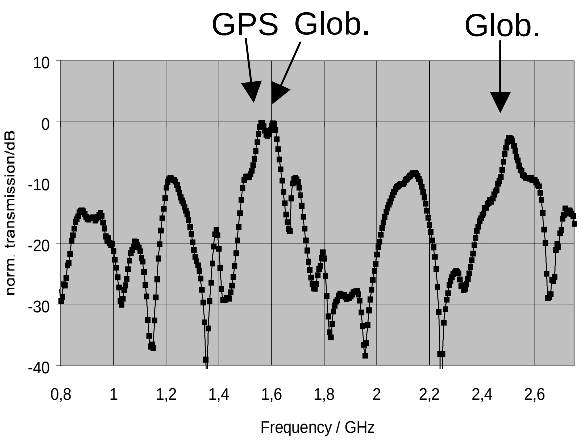


Fig. 4 Receiving characteristic for satellite radio services

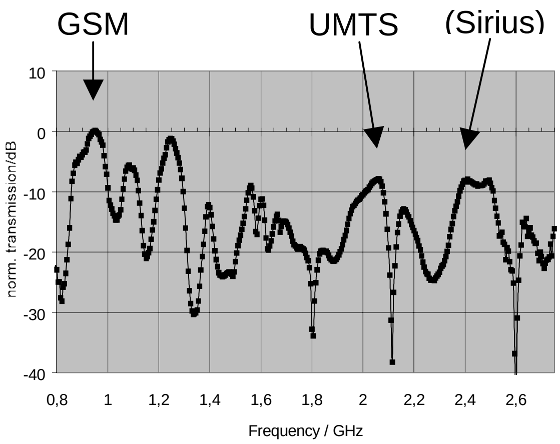


Fig. 5 Receiving characteristic for terrestrial services

As can be seen from the antenna measurement results of the first demonstrator shown in Fig.4, there is maximum transmission of the five-band antenna at the frequencies of the satellite services GPS and Globalstar. In Fig.5 the receiving behavior is at an optimum for the terrestrial services GSM and UMTS. Work is in progress to optimize the antenna to have also maximal transmission/reception at 2.35GHz (Sirius).

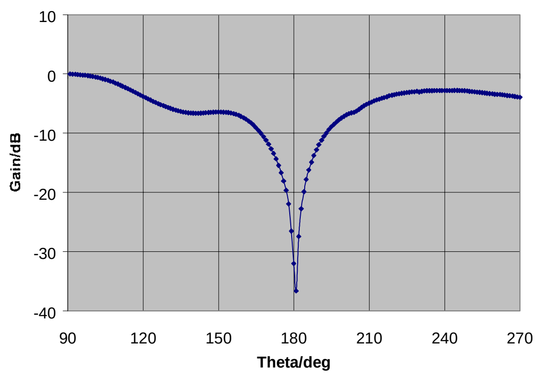


Fig. 6 Antenna characteristic at GSM 900MHz

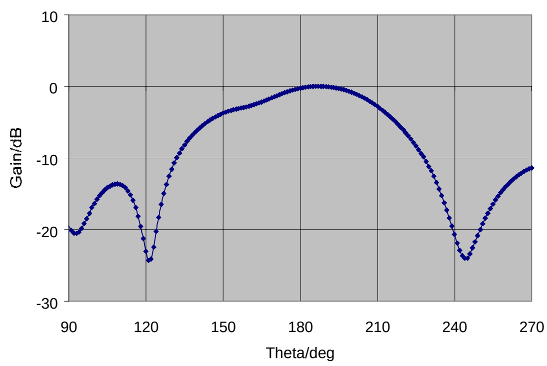
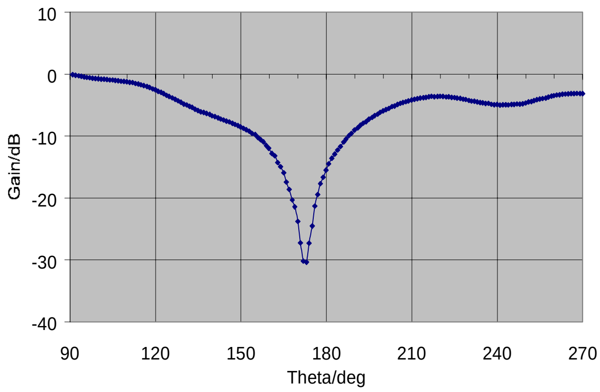


Fig. 7 Characteristic at GPS and Globalstar (1.6GHz)

In Figs. 6, 7, 8 and 9 the measured radiation characteristics for the different radio services GSM 900, UMTS, GPS and Globalstar are shown. As can be seen in Figs. 6 and 8, the five-band antenna fulfills the required horizontal main beam direction with vertically polarized field for the frequency bands of the terrestrial services.



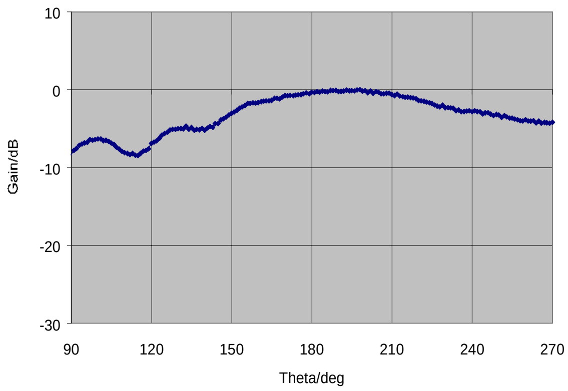


Fig. 8 Diagram at UMTS 2.0GHz

Fig. 9 Diagram at Globalstar 2.5GHz

In Figs. 7 and 9 is shown that the required vertical main beam direction occurs with circular polarized field for the frequency bands of the satellite services. In addition, the symmetry of the antenna yields, as required, an omnidirectional radiation characteristics in the horizontal plane.

CONCLUSIONS

A five-band antenna concept has been developed, realized and investigated for the reception and transmission of various terrestrial and satellite services. A feeding circuit is developed for the services GSM900, UMTS, GPS and two frequency bands of Globalstar. The radiation characteristics of the five-band antenna fulfills the requirements for all radio and navigation services.

REFERENCES

[1] A. Adrian, D.H. Schaubert, „Dual aperture coupled microstrip antenna for dual or circular polarization,“ *Electron. Lett.*, Band 23, S. 1226-1228, Nov. 1987

[2] C.S. Lee, „Planar dual-band microstrip antenna,“ *IEEE Trans. Antennas Propagat.*, Band 43, Nr. 8, S. 892-894, Aug. 1995

[3] Z.D. Liu, P.S. Hall, „Dual-frequency planar inverted-F antenna,“ *IEEE Trans. Antennas Propagat.*, Band 45, Nr. 10, S. 1451-1458, Okt. 1997

[4] S. Egashira, T. Tanaka, A. Sakitani, „A design of AM/FM Mobile Telephone triband antenna“ *IEEE Trans. Antennas Propagat.*, Band 42, Nr. 4, S. 538-540, April 1994

[5] J. Wang, R. Fralich, C. Wu, J. Litva, „Five-band aperture coupled stack antenna,“ *Electron. Lett.*, Band 26, S. 2067-2068, Dez. 1990

[6] H. Lindenmeier, J. Hopf, L.Reiter, J. Brose, R. Kronberger, “Car Antenna systems for multimedia applications” *VDI Berichte* Nr. 1547, 2000 pp. 741-770, Baden Baden, Oct. 2000

[7] S. Lindenmeier, J.F. Luy, P. Russer, "A multifunctional antenna for terrestrial and satellite radio applications", *MTT-S Digest*, Vol.1, pp.393-396, Phoenix, 19.-25.5.2001