# Sectorial cylindrical patch antenna for broadband at sea wireless nodes installed on vessels

Arkadiusz Byndas(1), #Pawel Kabacik(1), Fritz Bekkadal(2) and Kay Endre Fjørtoft (2)
(1) Institute of Telecommunications, Teleinformatics and Acoustics, Wroclaw University of Technology, 50-370 Wroclaw, Poland
arkadiusz.byndas@pwr.wroc.pl pawel.kabacik@pwr.wroc.pl
(2) e-Maritime, Marintek, 7052 Trondheim, Otto Nielsens Veg 10, Norway
fritz.bakkadal@marintek.sintef.no kay.fjortoft@marintek.sintef.no

## 1. Introduction

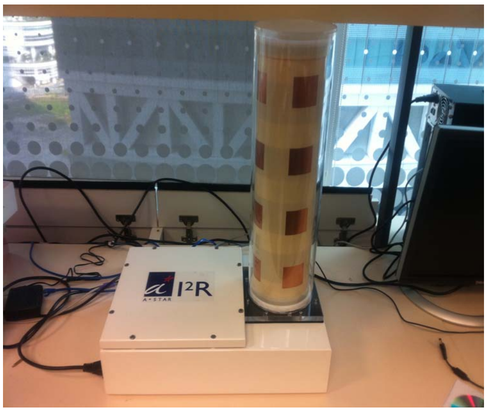
The paper presents a concept of the cylindrical antenna for broadband networks to be deployed on seas and oceans where traffic is dense. An important leading application of cylindrical antenna arrays, are becoming broadband wireless systems with mobile nodes and ad-hoc set-up topology. One of the main network types is the IEEE 802.16-2004 standard designed for long-range wireless broadband access. It uses a TDMA-based scheme in media access control (MAC) level and orthogonal frequency division multiplexing (OFDM) at the physical layer. At the MAC layer the IEEE 802.16d supports two modes, point-to-multi-point (PMP) mode and mesh mode. The main reasons driving interests in the cylindrical antennas for such networks, is their ability to provide gain advantage for radio link budget and offering design opportunities to spatial access. The presented cylindrical antenna array is able to provide, either overlapping several sector beams or by little disturbed omnidirectional pattern in the azimuth plane. In practical terms, the main evaluation criterions of such cylindrical antenna arrays are link radio performance and range of robust communication with implemented protocols. Furthermore, little troublesome operation and durability are important to antenna evaluation.

## 2. Cylindrical Antenna Array with Sectoral Beams

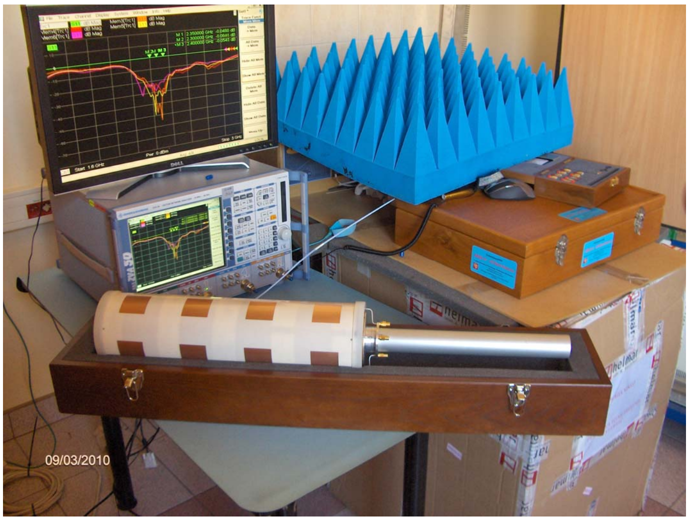
Designed and manufactured antenna model with its radome removed is shown in Figure 1. Patches are manufactured with composite panels made to match the circumference of a cylindrical surface. The antenna model is made to maintain smooth cylindrical form of both patch and ground surfaces. The manufactured antenna has four columns consisting of four patches each. Each column has its own power dividing network enabling feeding of as many columns as there are in the antenna.The entire feed network is accommodated inside the cylinder. Power dividing network is made on a single layer-laminate. In certain instances, it is desirable to broaden network band or increase isolation between branches. Then, use of a bonded two laminate layers can become necessary to meet these technical demands.

The antenna is for the S-band operation and its outer diameter is 120 mm. The chosen diameter value is given by the conclusion of carried out analysis focused on four sector beam pattern. The omni-pattern design brings other most preferred diameter values and they depend on permissible amplitudes of ripples in the azimuth plane. Patch element layout is also depending on the chosen pattern category: sectoral or omni. The important to the gain is a number of element rows in the cylinder. That factor, must be trade-offs against permissible beamwidth in the vertical plane (range of spatial movements – rollings and pitchings - of the vessel due to waves). Discussed beneath three patterns call for various meshes of patch elements. Substantial differences are faced when the design is updated onto the dual-polarized array. Then, the preferred patch shape may become circular one than the rectangular one. One of the most important advantage of the presented antenna array are physical features supporting efforts aiming at minimizing impact of weather conditions, such as more comfortable implementation of de-icing.

With selected generic concepts we have run computer simulations. Most often we have used CST Microwave Studio. The analysis have been concentrated on the S-band, as the band is well suited for technology demonstration and may find wide application in systems operating at coastal waters.




antenna integrated with A-Star radio modem




antenna in microwave laboratory

Figure 1: The presented cylindrical antenna

## 3. Results

With selected generic antenna concepts we have run computer simulations, most often making use of CST Microwave Studio. The antenna design was generally for demonstration purposes (around 2400 MHz frequencies). Cylindrical arrays making use of through-slot coupled patches used in the array, suffer from strong couplings between patch elements. These couplings are primarily not due to surface wave propagation, but due to presence of backward radiation caused by feed slots in the cylindrical antenna ground. It is one of the most serious design challenge. Measured return loss characteristics for each of four columns in the array prove good impedance match at every column (Fig. 2).

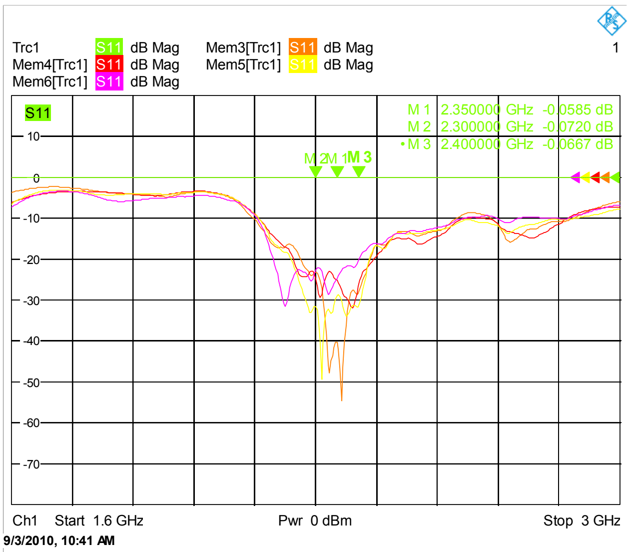



Figure 2 : Measured return loss at the input ports of four columns of the cylindrical antenna array developed for maritime applications

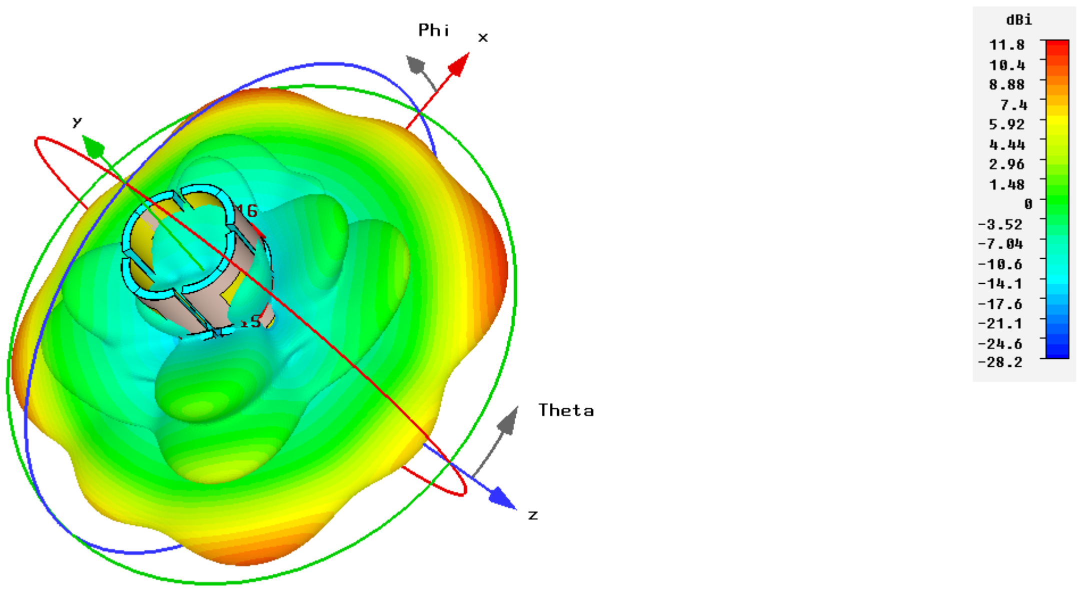


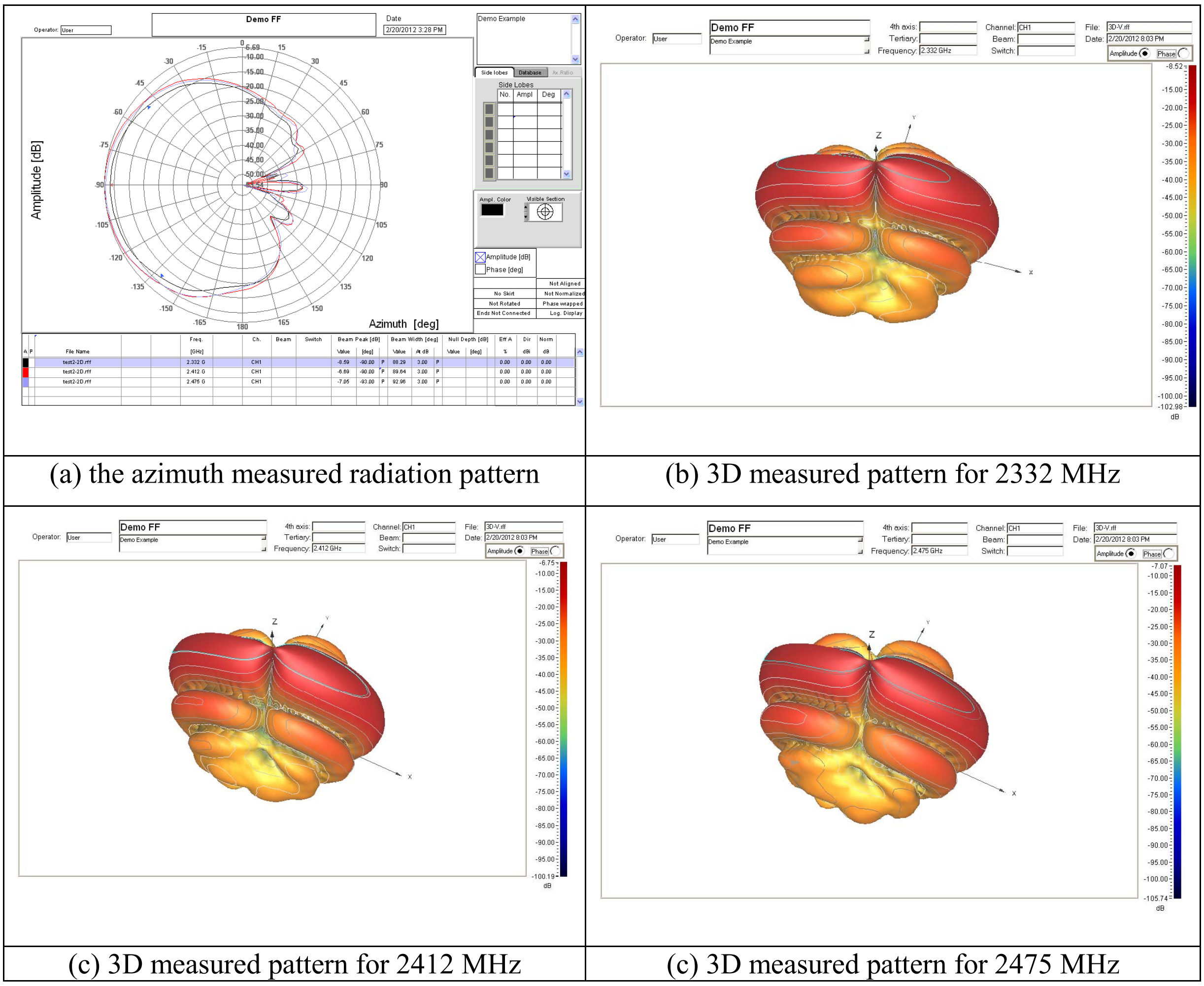

Figure 3 : One of combined radiation patterns calculated (with CST) during feasibility studies on coverage in the azimuth plane. All sixteen elements fed with the same amplitude and the same phase in the antenna array (f=2400 MHz)

Several studies aimed at optimum antenna feed for particular properties of the radiation pattern both in the azimuth and in the elevation planes. One of the case study results are plotted in Fig. 3. Radiation pattern were measured with the 2D and full 3D systems for a few frequencies between 2320 and 2465 MHz. Examples of measured radiation pattern results for different frequencies are presented in Fig. 4. In a case of the 3D pattern, the laboratory setup used a liner probe. The data file software at the laboraotry was unable to combine orthogonal field components together.

The antenna has four sectorial beams operating independently at their feed level. The design is generally not optimized for operating adjacent beams in pairs or altogether. Measured gain values for each antenna column were 12.1 to 13.6 dBi and increased with frequency. In order to develop the omni-pattern, quite different mesh must be used for patch element placement on the cylinder (however, the same diameter can be used).

## 4. Summarizing Comments

Cylindrical arrays prove they are highly attractive for wide applications in emerging wireless networks deployed on travelling nodes. Results of electrical tests have revealed major influences of the azimuth radiation pattern on system robustness. The direct influence is on actual link budget performance. But more troublesome can easy become the consequent indirect influence on communication protocol stability, when more than one lower-end node, are able to undertake communication with the same higher-end node in the backbone network.




(a) the azimuth measured radiation pattern | (b) 3D measured pattern for 2332 MHz

(c) 3D measured pattern for 2412 MHz | (c) 3D measured pattern for 2475 MHz

Figure 4 : Measured vertically linear polarized radiation pattern in (a) the azimuth plane and in (b,c,d) in the 3D plot for three frequencies

## Acknowledgments

The authors acknowledge co-funding of the presented research by European Space Agency and ARISS programs over many years, Norwegian MarCom project and MarSafe project. Technical discussions by the staff of A-Star in Singapore and performing there antenna measurements, field trials on land and on sea is highly appreciated.

## References

[1] Norwegian MarCom program http://www.marcom.no/
[2] Norwegian Marsafe program http://www.sintef.no/Projectweb/MARSAFE/
[3] Australian program http://antarcticbroadband.com/about/
[4] Norwegian program MareNor http://www.sintef.no/home/MARINTEK/Projects/Maritime/MARENOR--Maritime-radio-system-performance-in-the-High-North/
[5] M. Hornik, P. Kabacik, "Increasing integration in composite patch antenna arrays for dual-band and dual-polarized uses," Proceedings of Progress in Electromagnetic Research Symposium, PIERS 2010, Boston, July 2010.
[6] P. Kabacik, G. Jaworski, M. Hornik, T. Maleszka, P. Gorski, D. Wydymus, „Columbus/ISS CP dual-band, slim antennas made with a composite multi-layer panel," 30th ESA Antenna Workshop on Multiple Beam and Reconfigurable Antennas, ESTEC, Noordwijk, The Netherlands, May 2008.