Design of a Broadband HF Antenna for Multimode Naval Communications—Part II: Extension to VHF/UHF Ranges

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***Abstract*—This letter proposes a broadband antenna system with omnidirectional features, operating from 2 to 440 MHz. The basic antenna structure is the bifolded monopole, recently proposed as multimode high-frequency (HF) naval antenna, which is here augmented with a top-mounted discone mainly operating in the very-high-frequency (VHF) band. A mechanical and electrical integration strategy, which can be also extended to other antenna typologies, based on the lumped impedance loading to reduce the interantenna coupling, is described.**

***Index Terms*—Broadband antennas, HF antennas, shipborne antennas, software defined radio.**

I. Introduction

RECENT advances in the software-defined radio (SDR) technology [1], [2] and their application to naval communications have originated a growing interest in compact broadband antenna systems. Currently, naval links are typically handled by a multiplicity of narrowband tunable radiators. The resulting multiantenna scenario requires huge spaces and complicated feeding networks onboard the ship. Broadband antennas, though not so common, are also used in naval environments, but their bandwidths are generally less than 10 : 1. Electrically loaded wire antennas can be used to cover the whole high-frequency (HF) range [3]–[5], while discone and log-periodic radiators typically serve the very-high-frequency/ultrahigh-frequency (VHF)/(UHF) ranges. Arrangements of different antennas have already been discussed in [6] and [7]; however, these solutions refer to not so wide frequency ranges.

In [4], the authors introduced the bifolded monopole having 2–40-MHz bandwidth (HF range) and the capability to provide sea-wave and sky-wave links. This antenna was loaded by lumped circuits automatically chosen by a genetic algorithm (GA) optimizer [8].

This letter describes the extension of the operation bandwidth of the bifolded antenna up to 450 MHz. This is accomplished by a tight integration with a VHF broadband radiator, such as a discone antenna, placed at the top of the HF structure. The novelty of this approach is the feeding strategy, which should minimize the interantenna coupling. In this context, the purpose of the integration consists in the design of a broadband system having two separate input ports for the HF and VHF channels, where each subantenna retains about the same electromagnetic performances as in the standalone configuration. This is a strong challenge, particularly in the HF-band, since the VHF feeding cable could strongly interact with the HF antenna, and the discone modifies the original bifolded geometry by extending its height. In this perspective, a solution involving the tuning of the HF antenna impedance loading is presented.

Manuscript received October 10, 2006; revised January 26, 2007.

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Digital Object Identifier 10.1109/LAWP.2007.893094

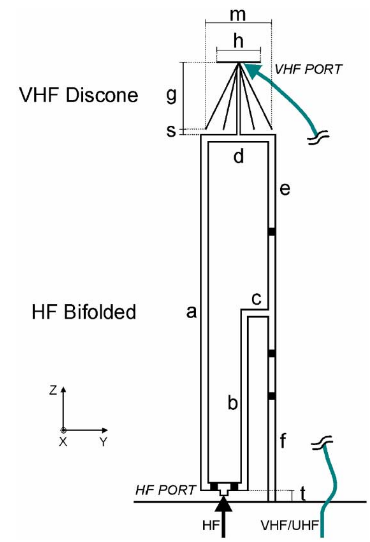
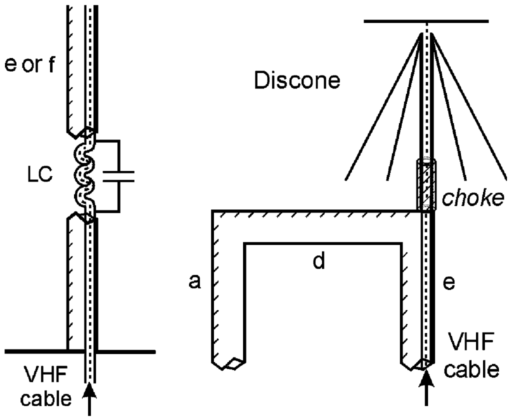


Fig. 1. Two-ports antenna system obtained by combining the bifolded and the discone radiators. Dimensions (in meters): a = 12, b = 6, c = 0.8, d = 2, e = 6, f = 6, g = 2.17, h = 1.55, m = 1.9, s = 0.2, and t = 0.4. Bifolded pipes diameter = 0.1. Discone wires diameter = 0.004. Black squares indicate the impedance loads in the original bifolded monopole design in [4].

II. Integration Strategy

With reference to the bifolded-discone arrangement of Fig. 1, the new proposed integration requires that the VHF feeding cable runs along (or inside) one of the vertical (hollow) conductors of the HF structure, which serves as a mechanical and electrical support. Since the HF antenna is loaded by lumped circuits, which interrupt the bifolded, they could prevent the VHF feeding cable from reaching the discone.

In particular, the bifolded antenna originally proposed in [4] was equipped with three loads on the vertical right conductor (“e” and “f” wires in Fig. 1) and no load on the left branch “a”. The VHF feeding cable cannot run inside



(a) (b)

Fig. 2. (a) Inductor of the LC-parallel circuit is obtained by twisting the VHF cable itself. (b) HF-choke used to suppress the induced currents on the discone antenna.

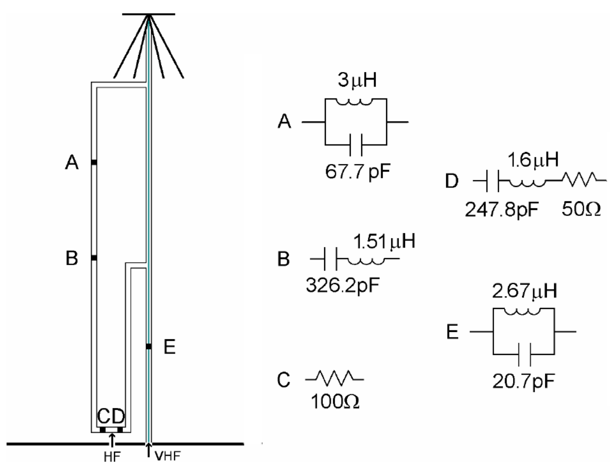


Fig. 3. Reoptimized bifolded-loading configuration. An LC-parallel circuit (tagged by "E") was selected by the GA on the right vertical conductor. When using a coaxial cable of diameter 5 mm, for instance, the inductance in the circuit "E" corresponds to a coil of ten turns, of length 10 cm and diameter 5 cm. The HF transformation step-up ratio was set to 4 as in [4].

the unloaded conductor "a" because the HF source would be short-circuited. However, the VHF feeding cable may run inside the HF-grounded conductors "e" and "f", but the impedance loading of the antenna needs to be modified with the purpose to leave these wires unloaded or, at least, to load them with only parallel inductor–capacitor (LC) connections. In the latter case, the required inductance may be obtained by twisting the VHF cable itself [Fig. 2(a)].

III. Performances Estimation

The performance of the bifoded-discone system is evaluated by means of the method of moments (MoM) [9] under the assumption that the HF antenna is placed over a perfect ground plane and by assuming the wires made of aluminum. For the sake of simplicity, an eight-radials discone is considered. This antenna has a voltage standing-wave ratio (VSWR) < 3 in the 40–440-MHz range, but the proposed integration can be also applied to different and better performing monopole-like VHF

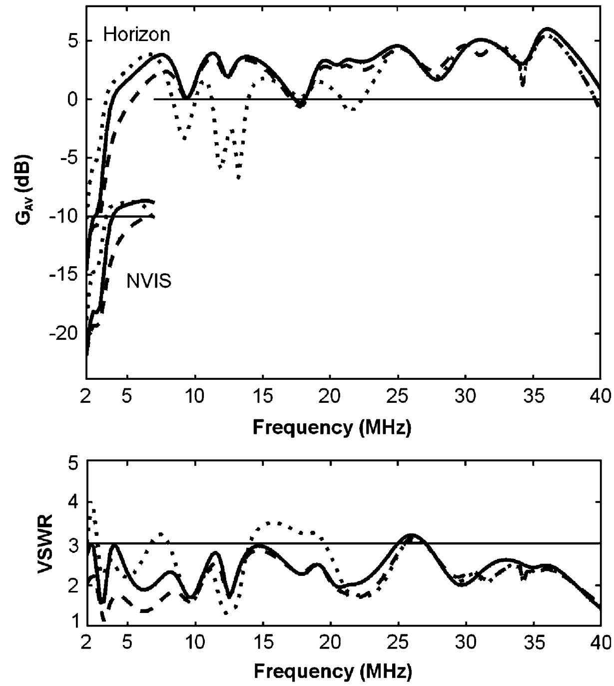


Fig. 4. HF performances: ϕ-averaged gain at horizon ($\theta = 90°$) and NVIS ($\theta = 20°$) and VSWR of the following antenna systems: standalone reoptimized bifolded (solid line), unchoked bifolded + discone (dotted line), bifolded + discone and finite impedance model ($|Z_s|/\mathrm{sq} = 500\Omega$ as in [10]) for the HF-choke in Fig. 2(b) (dashed line).

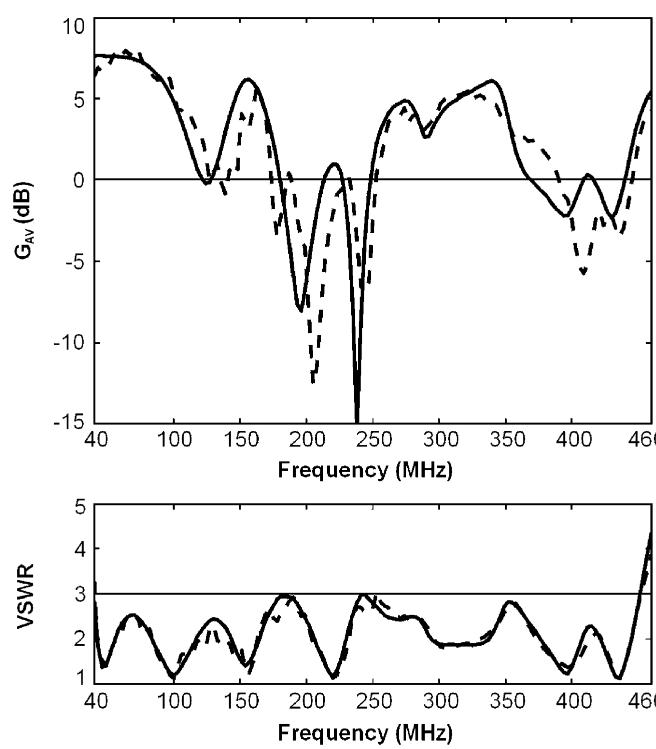


Fig. 5. VHF performances: VSWR and ϕ-averaged gain at horizon ($\theta = 90°$) of the discone antenna in two different configurations: discone on the bifolded in Fig. 3 (dashed line), and standalone discone placed at the same height from the ground plane (solid line).

antennas. The authors have numerically verified that the inter-antenna isolation improves if the discone is placed far from the

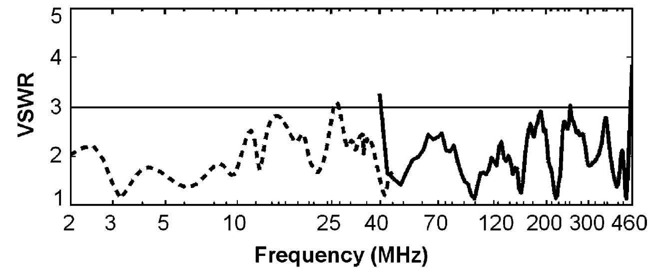


Fig. 6. VSWR of the integrated antenna system in Fig. 3 in the overall 2–440-MHz range. Bifolded VSWR (dotted line) was extended up to 45 MHz.

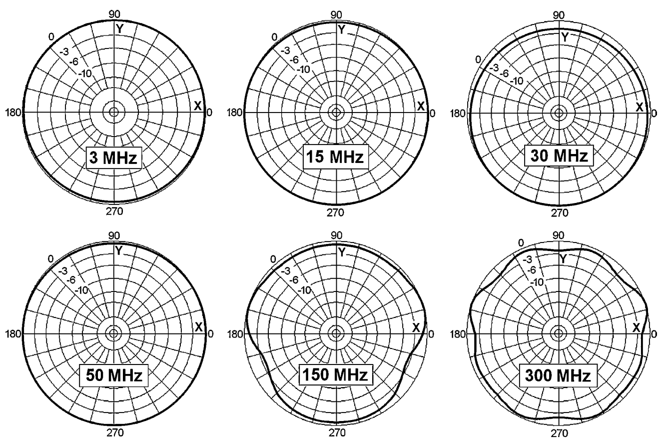


Fig. 7. Normalized horizontal gain with respect to the maximum value at different frequencies for the integrated antenna system in Fig. 3. The structure is placed as in Fig. 1 with respect to the reference axis.

HF port, e.g., at the top of the right conductor “e” (Fig. 3). The tuning of the impedance loads on the HF antenna is achieved by the same GA approach as in [4].

The best reoptimized antenna requires an LC-parallel circuit on the conductor “f” (tagged with “E” in Fig. 3), while four circuits are placed on the other branches. The performances in the HF-band are shown in Fig. 4 and compared with those of the standalone bifolded. Because of the induced currents on the discone, a slight degradation of the VSWR and a lowering of the gain occur between 8 and 20 MHz. This can be avoided by using HF-choke mechanisms [Fig. 2(b)], for instance, obtained by means of soft magnetic-material layers as suggested in [10].

The VHF antenna behavior, instead, is substantially independent on the particular HF antenna impedance loading configuration. The discone VSWR and averaged horizontal gain after the integration were computed and compared with those obtained at the same height from the ground plane, without the supporting HF structure. As shown in Fig. 5, the VHF antenna is well matched in the whole 40–440-MHz range.

The nulls in the gain around 200 and 400 MHz are due to the intrinsic discone antiresonances rather than to the coupling with the bifolded antenna.

The resulting VSWR of the integrated antenna system is shown in Fig. 6. Because of its low VSWR values, the bifolded antenna could be used up to 45 MHz. The normalized radiation patterns on the horizontal plane are represented in Fig. 7, where a good omnidirectionality can be observed at all the frequencies.

IV. Conclusion

The proposed integration of an HF and a VHF antennas theoretically allows to obtain a radiating system with an overall 220 : 1 bandwidth. The VHF antenna has a good optical visibility and the coupling between the radiators is minimized by providing a great isolation between their input ports and by taking advantage of the tuning of the HF antenna impedance loading.

The same idea can be directly extended to other kinds of HF loaded antennas of mainly vertical size. The omnidirectional properties of the resulting radiating system, its main vertical extension and its broadband features, make it particularly suited to naval installations and to the emerging SDR technology.

Acknowledgment

The authors would like to thank G. Falcione of Selex Communications, Finmeccanica Company, Pomezia, Roma, Italy, for inspiration and funding, and Prof. P. Tognolatti for suggestions and helpful discussions.

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