The Hi-Q Series HF Submarine Antennas

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Abstract

For submarine applications, it is desirable to have broadband, efficient, extremely short HF antennas that can cover the whole band without the use of a complex internal/external tuning circuitry. A short monopole antenna is currently used except that it has the following disadvantages: it is not efficient and uses complex external tuning circuitry. During a previous program funded by the NAVY, an electrically efficient small packaged submarine antenna that operates at the HF band was developed using existing subminiature aperture technology. In this paper, we detail the HF submarine antenna technology and performance results focusing on existing efficient submarine HF communications antennas.

1. Introduction

The gain-bandwidth product of antenna is proportional to the volume of the radiating mechanism. This makes it difficult to achieve efficient, instantaneous in band performance in an electrically small package using traditional antenna technology. This is very important issue at HF frequency bands where the wavelengths range from 10 to 100 meters [1] [2]. Frequency tuning the radiator is a method of regaining some of the efficiency lost when reducing an antenna ideal electrical size. Current HF antennas used on submarines are very inefficient radiators. Currently an inefficient short monopole radiator is tuned via an complex antenna coupler mounted at the base of the radiating element by current submarine antennas. Our HF antenna with high efficiency eliminates unacceptable heat generated inefficient HF antenna radiators. The elimination of the complex antenna coupler (tuner) and heat exchange assemblies improves reliability; reduce maintenance and safety to personnel.

2. Antenna Description

The goal was to achieve a High Radiation Efficiency within a restricted Radome cylindrical size, the available space of a max. height of 92 inches and a max overall diameter of 4 inches in the GOTLAND submarine. The design principal used to achieve a Hi-Radiation Efficiency on the LOW end of the frequency spectrum (2-24 MHz) is an inductively tuned CAGE Capacity Hat antenna. The Hi end of the frequency band (24 to 30 MHz) the antenna acts like a very broadband monopole.

A unique TUNING mechanism that allows the EXTREMELY SHORT HF antenna be tuned continuously from 2-30 MHZ has been developed specifically for the HMS GOTLAND submarine. The HI-Q-4/2-30 Submarine Communications Antenna is a broadband, ultra small HF aperture, continuously tunable antenna operating in the 2-30MHz frequency band. The Antenna consists of a lower mast (drive motor 24 VDC or Stepper) an upper mast (Re-entrant Coaxial Caphat) and a loading coil, a cylinder and an antenna controller. Since the requirement is to be continuously tunable from 2-30 MHz, a tunable loading coil was added. The tuning coil has only one moving part which is the contactor. The contactor only moves in the vertical linear dimension.

Physically, the Submarine Communications Antenna, shown in Figure 1, is of a cylindrical shape with a maximum height of 50 inches and a maximum overall outside diameter of 5.940 inches. This antenna was developed for the US Virginia Class submarines.

Fig. 1: HI-Q-6/2-30 Antenna

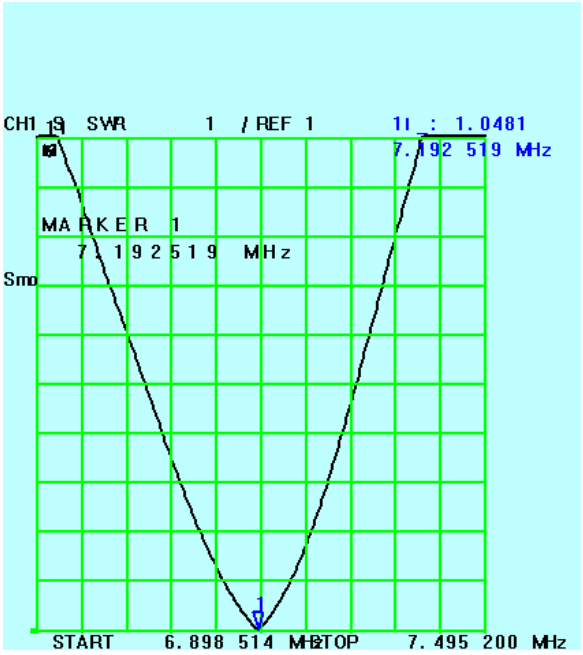


Fig. 2: Measured VSWR on The HP VNA

Electrically, the antenna retains an electrical a ¼ wave length at all frequencies of operation. VSWR'S of 1.5:1(nominal) were measured from 2-30MHz installed on the submarine in the intended operational environment (see photo of the HMS GOTLAND with the Mast extended to max. height. The HI-Q-4/2-30 RT-G is in the upper part of the mast.

The combination of a four inch diameter radiating element (Re-Entrant Coaxial Cap-Hat) and loading coil provides over a 200 % improvement in the antenna radiation efficiency, compaired to an antenna with a whip only of similar length.

The Hi-Q-4/2-30 RT-G antenna was installed on the HMS GOTLAND Swedish Submarine at the San Diego Submarine base.
The program was funded by the US Navy.

The latest EZNEC modeling code was used to theoretically predict the Hi-Q-6/2-30 OE-1538 antenna performance installed on the submarine's Sail, with mast extended to max. height.

The computed radiation pattern is shown In Figure 3.

Figure 4. is a plot of the Hi-Q-5/2-30 submarine antenna.

Figure 5. Is the Hi-Q Submarine antenna Family: Hi-Q-6 Max height is 50"
Max. diameter 5.940"
Weight is 22 lbs

Hi-Q-5 Max height is 54"
Max diameter 5"
Weight is 20 lbs

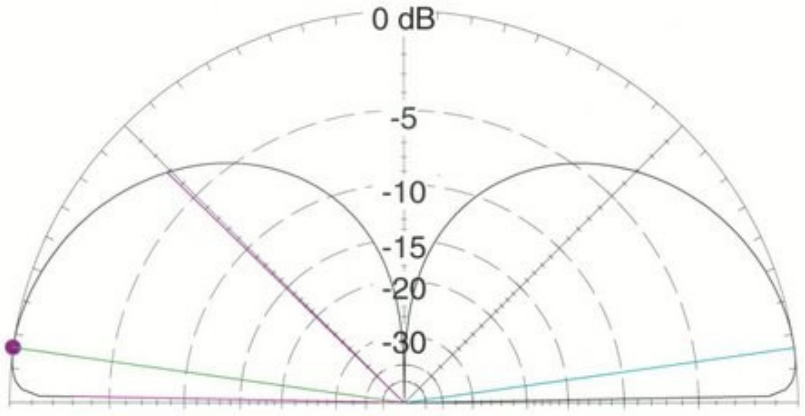
Hi-Q-4 Max height is 92"
Max diameter 4"
Weight is 18 lbs

Figure 6. Photo of HMS GOTLAND's Sail with the antenna mast fully extended.

Figure 7.Plot of the Hi-Q-5 OE 1538 antenna on the sail with mast fully extended.

Photo (on the HOT TIN ROOF) the Hi-Q-4-2-30 RT-G antenna in the fibreglass enclosure before inserting it in the submarines antenna mast.

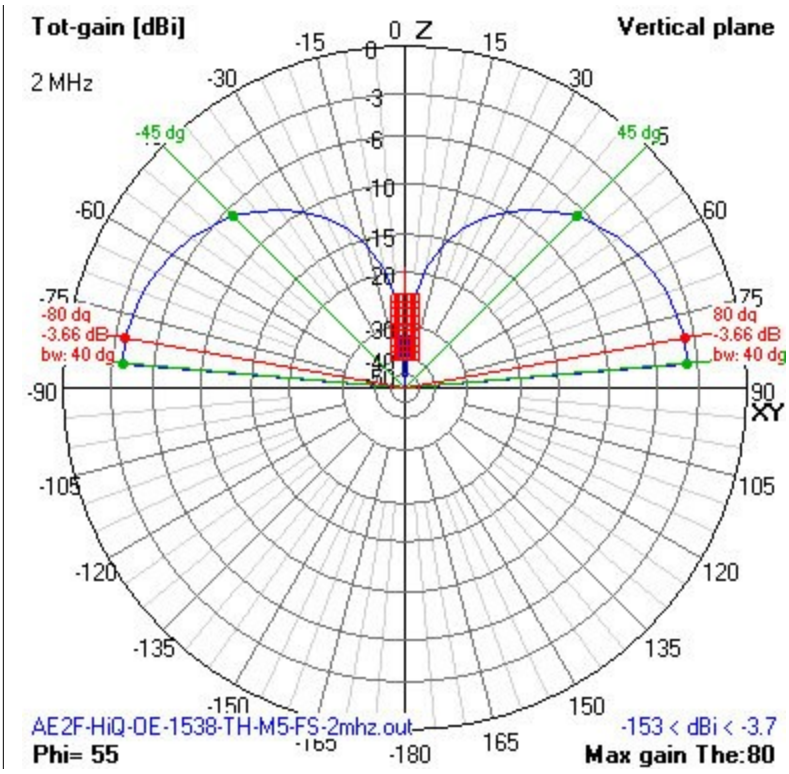
Total Field EZNEC+



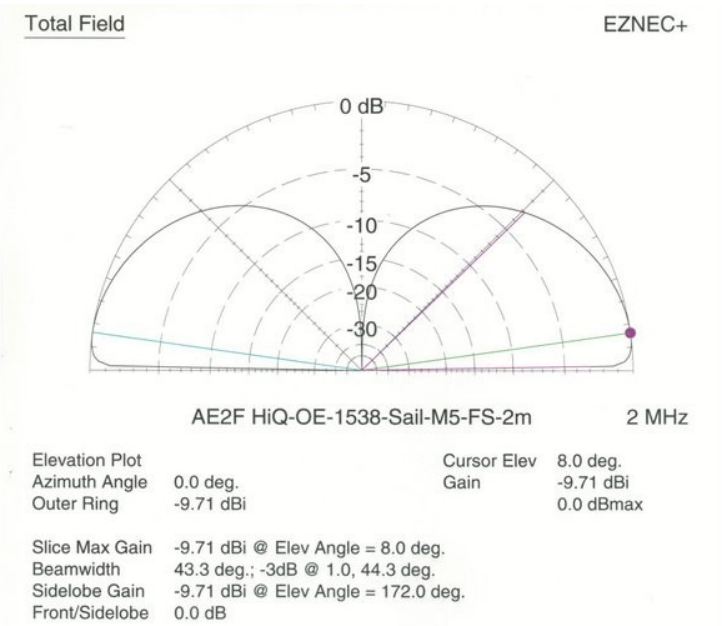
AE2F HiQ-OE-6 Sail+sub-bo 2 MHz

Elevation Plot		Cursor Elev	172.0 deg.
Azimuth Angle	0.0 deg.	Gain	-4.25 dBi
Outer Ring	-4.25 dBi		0.0 dBmax

Slice Max Gain	-4.25 dBi @ Elev Angle = 172.0 deg.
Beamwidth	43.4 deg.; -3dB @ 135.6, 179.0 deg.
Sidelobe Gain	-4.25 dBi @ Elev Angle = 8.0 deg.
Front/Sidelobe	0.0 dB



Plot of the Hi-Q-5-2-30 MHz submarine antenna.



Hi-Q-6 OE-1538 mounted in the mast fully extended , Computed Radiation Pattern and Gain

HMS Gotland HF Antenna Installation,
Mr. Frank PLONSKY and the HMS GOTLAND Communication Officer.

3. Preliminary Measured Results

The results of Preliminary radiation tests are as the following. On all of the desired frequencies the Hi-Q antenna has demonstrated good communications with typically 500 watts of RF SSB (maximum design power is 2kW) with a test maximum of 1 kW RF at the input. The Hi-Q simple test to the radiation Efficiencies of the Hi-Q design is to actually communicate on ALL frequency ranges a get signal reports in “S” units and dB’s over “S” 9. Two way communications on the Ham radio frequencies was confirmed. On all Ham frequencies listed below, the Hi-Q antenna has demonstrated good communications with typically 100 watts of RF SSB, at times the signal strength was 10 dB over “S” 9.

On 3.795 MHz From near San Diego California to Hawaii, China, Japan, Australia, New Zealand

On 3.798 MHz to South Africa

On 7.250 MHz daily contacts within USA and Canada,

On 14,200 MHz daily contacts with Europe.

On-18.0 MHz and 21.0 occasional contacts world wide

On 1.850 MHz contacts within USA and Canada in the winter months.

4. Conclusions

In this paper we have reviewed some of our calculated and experimental results on design of electrically small HF antennas using Hi-Q Antennas unique tuning mechanism and extremely short HF radiating elements. The designed HI-Q antenna has higher radiation efficiency then any other short HF submarine antenna designed to date. More calculated and measured results will be given in the presentation.

Reviewed by: Frank Plonsky, Retired US Navy Antenna Scientist

Note: *It was Mr. Plonsky, while at NAVSEA, who has managed the entire HMS Gotland HF Comm antenna upgrade from initial fhone call to Hi-Q antenna, testing and installation of it in the GOTLAND's antenna mast.*
We express our appritiation to Mr. Plonsky and his NAVSEA Team, who has endured the over 110 degree Califronia days while testing on our HOT TIN ROOF.

References

[1] LT. Longor, COMSUBLANT, 4 November, 1993, Submarine Communications Requirements, COMSUBLANT/COMSUBPAC Joint Letter 2000 Serial 00/08606

[2] David Tonn, Paul M. Mileski, Cari L. Hodge, "ON-SITE EFFIECTIVE HEIGHT MEASUREMENT OF HF ANTENNAS",Proc. Of the Antenna Measurement Techniques Association (AMTA '02), pp. 421-425.