Antenna size versus Sea clutter rejection: a new analysis of coastal radar performances and optimization

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***Abstract*— In the field of coastal surveillance radar, and more generally in maritime environment, the overall radar performance for the detection and tracking of small target is primarily linked to the capability of the radar to reject the sea clutter. Sea clutter is the radar signal return of the sea surface illuminated by RF waves and can often be a strong as the target radar return. A conventional method to counter sea clutter is to use very large antennas providing high angular resolution trying to optimize the signal to clutter ratio in the radar processing by defining the smallest possible illuminated cell of sea surface. This paper provides an in depth analysis of the pro and cons of large slotted waveguides antennas and shows that bigger is not better : Parasitic effects, correlated to antenna dimensions, in the beam forming process of big antennas tends to degrade the antenna performance and leads to the conclusion that the optimal antenna size is often smaller than the one currently used on existing coastal surveillance radars.**

I. Introduction

Derived from ship navigation radars, many coastal surveillance radars on the market are using the combination of a Magnetron pulse transmitter and a slotted waveguide antenna. Specification of these elements are often given separately and this paper will demonstrate that in a coastal radar, the structure of the antenna has a large influence on the transmit and receive pulses and that it is a clear limitation of performances that is not often taken into account by simulation software or final users when designing complete systems.

II. Slotted Waveguide Antenna

A slotted waveguide antenna is basically a waveguide used to conduct RF energy on which are placed slots (holes) creating leaks of energy all through the guide structure. Each slot can be assimilated to a single radiating element, such as a dipole, and the global antenna is the coherent combination of N in-phase radiating elements. Usually, the RF energy is fed through one end of the antenna (end-fired configuration) and propagates all along the guide structure. Each slot radiates electromagnetic energy and the coherent addition of each individual radiation creates the beam of the antenna.

In well known marine antennas and for a given central frequency operation, the spacing between slots is usually fixed around 0.6λ to provide a maximum radiation at 90° from the guide structure, we can draw two direct consequences:

Antenna gain is proportional to N, number of slots, and to antenna dimension L.

Antenna beam width in azimuth plane is inversely proportional to L.

The Gain of the antenna is related to elevation and azimuth beam width by:

$$G = 10\log(\frac{180}{\theta_{Az-3dB}}) + 10\log(\frac{180}{\theta_{El-3dB}})$$, angles in degrees.

Due to the planar structure of the antenna, slotted waveguide antenna usually have a vertical beam size around 20°, with little dependency on antenna dimension. This paper will focus on horizontal plane only.

A classical model of slotted waveguide antenna is an N elements linear array with uniform amplitude and spacing of the radiating element.

The radiated electric field E can be expressed as a coherent sum of individual fields, with the following equation:

$$E = E_1 + E_2 + ... + E_N$$

With can be reformulated by

$$E(total) = E(slot).AF$$

In which all slots are considered individually and the global antenna behavior is given by a coefficient AF, named the Array Factor and expressed by:

$$AF = \frac{\sin(\frac{N}{2}\Psi)}{\Psi\frac{N}{2}}$$

N being the number of slots and ψ expressed as:

$$\Psi = \frac{2.\pi d}{\lambda}\cos\theta - \beta$$

The Array Factor has only one maximum which occurs for θ=θm, the main lobe direction for the antenna, expressed by :

$$\theta_m = \cos^{-1}(\frac{\lambda\beta}{2.\pi d})$$

For β=0, all slots are in phase and the antenna radiates in a broadside direction (θ=90°) compared to the guide main dimensions.

If the frequency is modified, phenomena named squint takes place, leading to an antenna pointing to another direction, simply because the phase condition is not fulfilled anymore in the antenna structure.