MPAR: Waveform Design for the Weather Function

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***Abstract*— An integrated target/weather surveillance at medium range, i.e. for the Terminal Manoeuvre Area (TMA) in the frame of Air Traffic Control (ATC) and regional weather monitoring, is made possible by MPAR (Multifunction Phased Array Radar) techniques, allowing a single technology to satisfy different requirements. The guidelines for system design, needed for cost/benefit analysis, were described in a previous EuRAD paper [1]. As in many other radar applications, pulse compression is a key element to achieve the required MPAR performances with low-cost solutions using relatively low-peak-power Transmit/Receive modules. This paper describes a preferred novel solution for the waveforms to be used in the weather function of the MPAR. Performance comparison with more traditional codes is also presented.**

I. Introduction

MPAR (Multifunction Phased Array Radar) architectures for civil use have recently gained a significant interest, see e.g. the References of [1] and [8]; as an example, in the Next Generation Air Transportation System Integrated Plan by the Joint Planning and Development Office (USA) it is explained that MPAR can provide the greatly reduced scan times, high resolution, and multifunction capability required for the enhanced severe weather prediction and aircraft control. The study in [1] considers the fact that for an European-type environment, the TMA surveillance (up to 60 N.M.) is considered more important than the Airway Surveillance (up to 200 N.M.). The present study is related to TMA and Airport Surveillance, i.e. with a maximum range of 110 Km for both air targets and weather. In this frame, Active Phased Array techniques call for a number of S-Band Transmit/Receive Modules (TRM) per each of the four array faces of the order of ten thousands or slightly less (e.g. 9000); therefore, cost reduction for the TRM is the most significant aspect of the MPAR design, and implies a peak power per TRM of the order of 1 W or even less, and Pulse Compression has to be considered for the Medium Range (i.e. up to 110 Km) functions. The very critical Weather function will be mostly considered in the following.

II. The MPAR Architecture and the Power Budget

The proposed MPAR has four functions: ATC functions at short and medium range, and Weather functions at short and medium range. Table I shows the assumed requirements in terms of the coverage area and of the update time (time request to revisit a given resolution cell).

In order to cover the radar volume quickly enough, compatibly with the update time, the architecture uses large beams in transmission, while in reception, by Digital Beam Forming (DBF), employs many simultaneous narrow beams. For ATC functions 16 and 8 beams in azimuth at zero elevation are considered for short range and medium range respectively; these values are increased with elevation up to 24. For weather functions 4 and 2 multibeams are supposed for SR and MR respectively.

The number of pulses for ATC functions is variable in the beam: from 16 (two Coherent Processing Intervals, or CPI, each of 8 pulses) at low elevation , decreasing to 2 pulses at high elevations. With respect to the weather functions we considered the “agile beam scan” or “beam multiplexing” [9] to reduce the number of samples from a classical number of 64 or 128, highly correlated, sweeps, to 16 independent samples, without affecting the r.m.s. error for the estimated parameters of the precipitation.

Finally S-band (2.7 to 3.0 GHz) has been considered because of its low attenuation effects in rain, and of its standard use in ATC.

TABLE I
ATC and Weather Functions Requirements
(SR = Short Range, MR = Medium Range)

Functions	R_{MAX} (km)	Height (km)	Azimuth x Elevation	Update time T_F (s)
ATC SR	55	12	90° x 50°	2
ATC MR	110	12	90° x 40°	4
Weather SR	55	12	90° x 26°	60
Weather MR	110	12	90° x 15°	120

With respect to the power dimension, for ATC functions we have considered the radar equation to evaluate the peak power per active module supposing a SNR derived from $P_{fa}=10^{-6}$ and $P_D=0.9$, Swerling 1 target. For the Weather functions the peak power for module has been evaluated using the Probert-Jones equation [7] supposing a SNR = 10 dB with a minimum value of reflectivity of 10 dBz.

With an array antenna of 5m x 6m (roughly 8200 TRM) using an uncompressed pulse of 0.625 microseconds, the peak power per TRM is too large (order of ten watts) as shown in the 4th row of Table II, in which Table the execution time, the number of executions and the total time for each function in one cycle time are reported.

The peak power per TRM can be reduced using pulse compression. Considering a compression ratio equal to 128