REMOTE RETUNING OF X-BAND MINI WEATHER RADAR USING GROUND CLUTTER ECHOES

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Abstract

The magnetron of a X-band mini weather radar could drift mainly due to external factors such as temperatures, humidity etc. The central frequency of the radar receiver filter must remain perfectly aligned with the magnetron generated frequency in order to receive the maximum power and avoid rain underestimation problems. This work describe a simple and cheap technique developed to remote retuning a X-band weather radar using ground clutter echoes acquired during clear sky days. By statistically analyzing the power distributions of ground clutter echoes observed in clear sky conditions, it is possible to control the radar stability over a long time interval and to retune the radar. The technique is described and several results are reported.

Index Terms – Ground clutter echoes, Radar tuning, X-band weather radar.

I. X BAND RADAR NETWORK

Radar meteorology has always been one of the major research topics for the the Remote Sensing Group (RSG) of Polytechnic of Turin, local unit of CINFAI (Consorzio Interuniversitario per la Fisica delle Atmosfere e delle Idrosfere). Its own X-band mini radar system was developed in the past years in collaboration with Envisens Technologies s.r.l., spinoff of Polytechnic of Turin [1].

The first fully operational network of mini radars was set up starting from 2010 and now, in 2014, it is made up by 8 radar systems (Fig. 1): one in Turin town, Italy (2010), in Aosta Valley, Italy (2011), in Foggia, Italy (2012), in Palermo, Italy (2012), two in Israel in collaboration with the Hebrew University of Jerusalem (2012), one near Nizza Monferrato in Piedmont Region, Italy (2012) and one in Parma, Italy (2013).

Each radar acquires the real time maps and send them to a specific server where some specific services and applications have been implemented. Processed radar maps can be browsed on the official network web site (meteoradar.polito.it) where they are projected over a cartographic system. On the server side, specific applications and services are running [2].

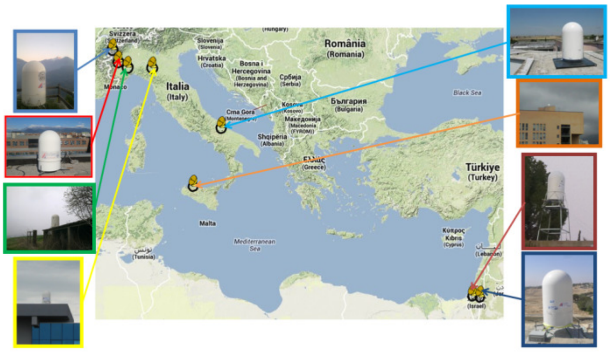

FIG. 1 – The X-band mini weather radar network in March 2014.

The radars are exclusively devoted to rain measurement and reach good performance thanks also to some specific developed calibration procedures.

II. THE "DETUNING" PROBLEM

To assure good performances in detection and measurement of rain, it is not only important that the radar is well calibrated, but it is necessary to control the stability of the overall radar system components. These sub-systems may suffer for some degradations due both to external factors, such as temperature fluctuations, humidity etc, and to equipment ageing and related issues.

Among all these problems, the frequency drifts of the magnetron is very common because all the radars are installed in open field and are exposed to different, and often extreme, weather conditions. In order to receive the maximum power back scattered by the rain cells, it is important that the receiver filter central frequency is completely aligned with the transmitted frequency by the magnetron, in order to avoid the so called "detuning" problem.

III. GROUND CLUTTER ECHOES TO DETECT A "DETUNING" CONDITION

According to RCA (Relative Calibration Adjustment) algorithm described in [3], originally proposed for a S-band ground radar, the Probability Distribution Function (PDF) of the clutter echo and, consequently, the corresponding Cumulative Distribution Function (CDF), should significantly change only if modifications on the radar systems occurred.

It is demonstrated in [4] that it is possible to use clutter echoes acquired during clear sky days, and properly statistically analyzed, to control the radar stability also for X-band mini weather radar. In particular an experiment is described: the radar receiver filter is intentionally detuned to establish which are the best statistical indicators to check if the system if properly working.

X-band mini weather radar receiver central frequency is controlled by a 8-bit register, and its value can be remotely modified. If a radar is supposed to be detuned, it is possible to turn off the clutter filter (usually enabled) and acquire clutter maps during clear sky days varying the value of such filter, in order to track the drifts of the magnetron.

To retune the radar using ground clutter echoes, the procedure is the following (note that all the operations can be done remotely and last less than 2 hours, thanks to the flexibility and the high configurability of the system):

- A set of clutter maps is acquired for different receiver filter code value (10 - 15 maps for each value are enough);
- considering each set of clutter maps acquired with different receiver filter code value, the CDFs are computed;
- A possible radar detuning condition is checked by observing the mean values.
- In case of system detuning, the losses are evaluated considering the difference between the mean value of the CDFs.
- The register filter code value for which the 90th percentile (and consequently the mean) reaches its maximum is the new value to be written in the register, in order to restore the tuning and track the magnetron drifts.

IV. EXAMPLE OF REMOTE RETUNING OF GILAT (ISRAEL) RADAR

The radar in Gilat (Israel) was installed in October 2012 within a scientific cooperation program between Italy and Israel.

After one year, during November 2013, the radar was heavily underestimating the rain. It was supposed to be detuned and the remote retuning procedure was applied during a clear sky day.

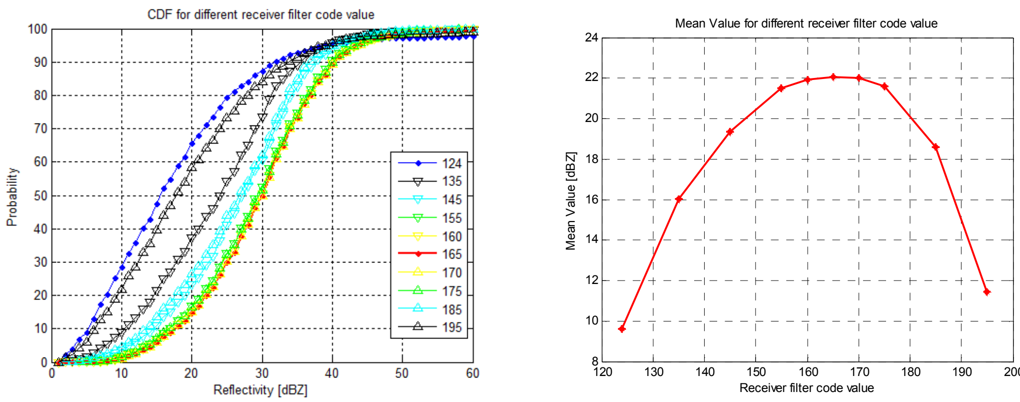

FIG. 2 – CDFs for different receiver filter code value on the left (a), and mean of the different distributions obtained with different receiver filter code value on the right (b).

The CDFs were evaluated it was immediately noticed that the radar was detuned: the receiver filter code value set during the installation was 124, blue line, and the new value for tuning was 165, red line (Fig. 2 (a)). According to the information provided by the analysis of the mean of the different distributions, the system was losing about 12 dB (Fig. 2 (b)).

The X-band mini weather radar was remotely retuned by setting the new receiver filter code value. The radar was then restarted with the clutter filter enabled in order to get only backscattered echoes coming from rain cells.

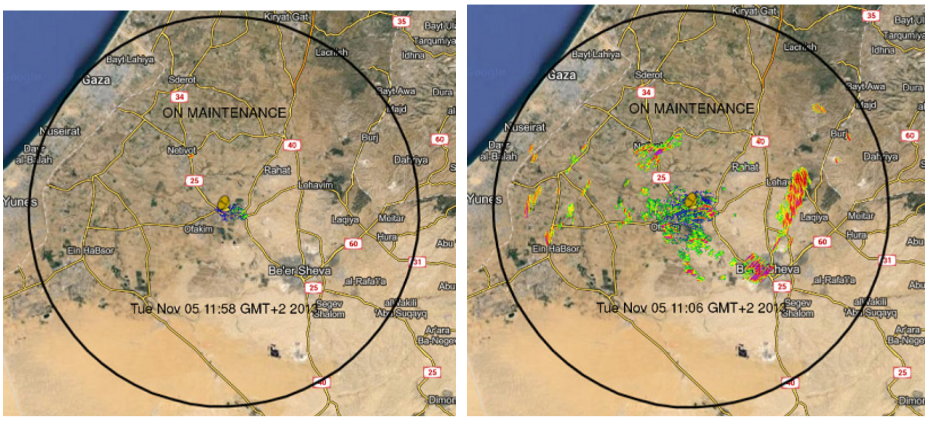

FIG. 3 – Example of clutter maps in detuning on the left (a) with receiver filter code value equal to 124, and after the retuning operation on the right (b) with receiver filter code value equal to 165. It is clear that the radar was heavily detuned because before the retuning operation the clutter echoes were very low.

V. CONCLUSION

A procedure to remote retune a X-band mini weather radar system is presented together with its application on an operative radar installation. The procedure is simple, does not require any additional software with respect to the standard software package to control the radar system (therefore it is cheap), and does not require too much time to be executed. The procedure works well and allow to retune a radar when a frequency drift of the magnetron occurs. Since this experience, the algorithm is periodically applied to compensate seasonal drift due to the mean temperature variations keeping the radar calibrated for rain estimation within a 2 dB interval.

REFERENCES

[1] M. Gabella, R. Notarpietro, S. Bertoldo, A. Prato, C. Lucianaz, O. Rorato, M. Allegretti and G. Perona, "A Network of Portable, Low-Cost, X-Band Radars", *Doppler Radar Observations - Weather Radar, Wind Profiler, Ionospheric Radar, and Other Advanced Applications*", Dr. Joan Bech Ed., InTech, 2012, pp 175-202.

[2] S. Bertoldo, C. Lucianaz, O. Rorato, M. Allegretti, A. Prato, G. Perona, "An operative X-band mini-radar network to monitor extreme rainfall events with high time and space resolution", *Engineering technology and applied science research*, vol. 2(4), pp 246-250, 2008.

[3] D. S. Silberstein, D. B. Wolff, D. A. Marks, D. Atlas and J. L. Pippitt, "Ground Clutter as a Monitor of Radar Stability at Kwajalein, RMI", *Journal of Atmospheric and Oceanic Technology*, vol. 15(11), pp 2037-2045, 2008.

[4] S. Bertoldo, R. Notarpietro, M. Branca, G. Dassano, C. Lucianaz, O. Rorato, M. Allegretti, "Characterization of the receiver filter of a X-band weather radar to improve the performance of an application to control the radar stability", *International Conference in Electromagnetics in Advanced Applications*, Cape Town, South Africa, September 2nd – 7th, 2013, pp. 1040-1043.