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Development of a Multichannel Analyzer for Radioactive Isotopes Detection

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ABSTRACT

This report is a summary of work carried out at Defence Laboratory DRDO Jodhpur during internship as a part of Masters of Computer Application. The report is the brief description of study about the Multichannel Analyzer and crystallization of work.

The work helps in developing insight on a state of the robust technology [MCA] to identify radioisotopes during the nuclear emergency.

Study of Multichannel Analyzer is in the way that it would be able to store the spectrum that is to be displayed. Ferventness of MCA spectrum is classified further in two parts respectively which are Energy spectrum that is Calibrated and Pulse Height spectrum which is non-calibrated. A new approach to problem solving is in the direction of feasible survey, and in addition to this requires a remarkably low-down time by measuring the spectrum pattern on-site in nuclear emergency. The solution is the so called near-field spectrum pattern measurement method, which requires mathematical parameters and algorithms.

KEYWORDS: *radar; Spectrum; near-field measurement; radiation pattern*

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I. INTRODUCTION

Radar antennas are exposed to various environmental stresses, which may lead to performance degradation over time. To maintain the service continuity of air traffic control (ATC), regular performance checks are highly recommended to prevent surveillance malfunction. In practice radiation pattern of an antenna is measured in an anechoic chamber. In the case of a continuously operational radar, the disassembly, transport to an anechoic chamber, measurement, return and reassembly would lead to significant service outages, and would be practically impossible. A new approach to problem solving is feasible, and in addition to this requires a remarkably low-down time by measuring the radiation pattern on-site in war as well as in peace situation. By definition, the radiation pattern of an antenna is the so called far-field, directional electromagnetic power distribution. In real environment, direct measurement cannot be realized. The various objects of the environment would disturb the measurement by causing multiple propagation path due to reflections. Another disturbing factor is in band interference; far away from the antenna, the radar signal is attenuated, that its power level is comparable to signals from other source. The solution is the so called near-field radiation pattern measurement method, which requires mathematical transformation of the raw measurement.

II. NEAR-FIELD MEASUREMENT OF THE RADIATIONPATTERN

The far-field radiation pattern measurement is simple in that manner, it requires only the measurement of the power level of the received signal. In contrast, the near-field method requires both magnitude and phase measurement of the signal. Typical measurement set up can be seen in figure 1., it requires a vector network analyzer.

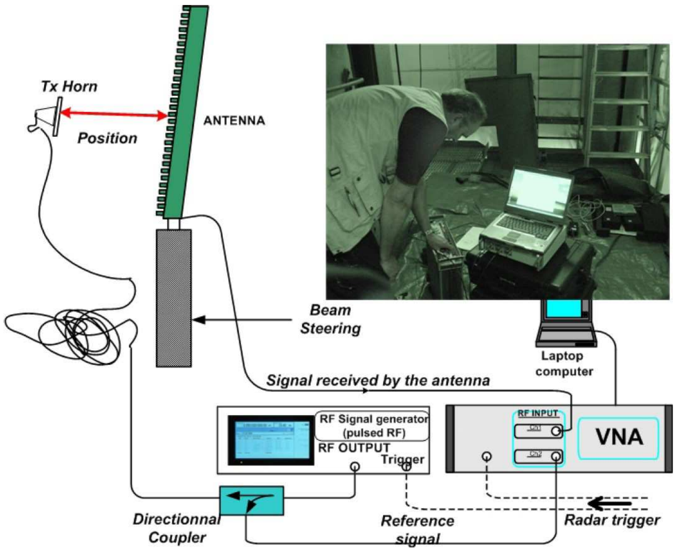


Fig 1 Near-field measurement set

Because both magnitude and phase information are presented the measurement is actually a hologram. This can be transformed into far-field radiation pattern, which then back projected to field distribution of the aperture. Any deviation in the aperture distribution can be detected, and the defective antenna elements can be repaired or replaced.

III. RADAR ANTENNAS

Basically, there are two types of radars used in air traffic control. The first one is the primary surveillance radar (PSR), the other is the secondary surveillance radar (SSR). Literally only the first one is radar, the SSR uses two-way radio communication to detect and identify airplanes, nevertheless both have an inevitable role in ATC. Usually, the primary radar use cosecant squared fan-beam to measure distance and direction, therefore three-dimensional radiation pattern checks is recommend. The secondary radar uses a fan-beam, that is narrow in azimuth, but wide in elevation, so horizontal plane radiation pattern checking is sufficient in most cases. However, in case of MSSR there are three different beams formed, the so-called sum, delta and omega channel. Therefore, the outage time can be decreased and the synchronous angular sampling is more practical, if these radiation pattern measurements are concurrent.

In general, vector network analyzers have two ports; they can measure only one channel at a time. For faster measurement a multichannel vector network analyzer is required.

IV. DEVELOPMENT OF A MULTICHANNEL ANALYZER

For concurrent measurement of the SSR antenna's radiation patterns, at least 3 channels are required, capable of measuring magnitude and phase. By design, the developed instrument is capable of simultaneously measuring 4 channels. The device has one transmitter output, and four receiver inputs, which form a coherent multichannel test transceiver system. The main parameters of the developed analyzer are shown in table 1.

TABLE I MAIN PARAMETERS

Frequency range	1.0 - 1.5 ; 2.7 - 3.6 GHz
TX output power	max 10 dBm
RX sensitivity	better than -80 dBm
Dynamic range	> 78 dB
Battery operating time	> 2 hours
Control and data interface	RJ-45 / Ethernet
External trigger	PRF, NRP, ACP, Lift control
TX mode	CW / Pulse
Pulse delay	1us ... 3ms
Pulse length	1us ... 3ms
Phase shift	-180 ... +180 °
PRF trigger	100 ... 8000 Hz
PRF source	external / internal / detector
NRP source	external / internal
Antenna RPM	5 ... 60

The analyzer can be operated by battery, while it can be controlled by a laptop. External trigger inputs can receive Pulse Trigger, Azimuth Change Trigger, and North Reference Pulse trigger.

This test system enables the fast measurement of the secondary radar antennas, while using the fourth input as interference detection, the embedded lift control module allows the measurement of three-dimensional (cylindrical) radiation patterns. The instrument can be operated in a passive mode, where the transmitted signals are generated by the radar itself. In this case a microwave coupler provides the reference signal for coherent reception. The measurement can be carried out using continuous or pulsed signals. The pulsed method is useful, when the high-power amplifier of the radar' s transmitter is used, which can be operated only in pulsed mode.

Fig 2 BURS14 4 Channel VNA

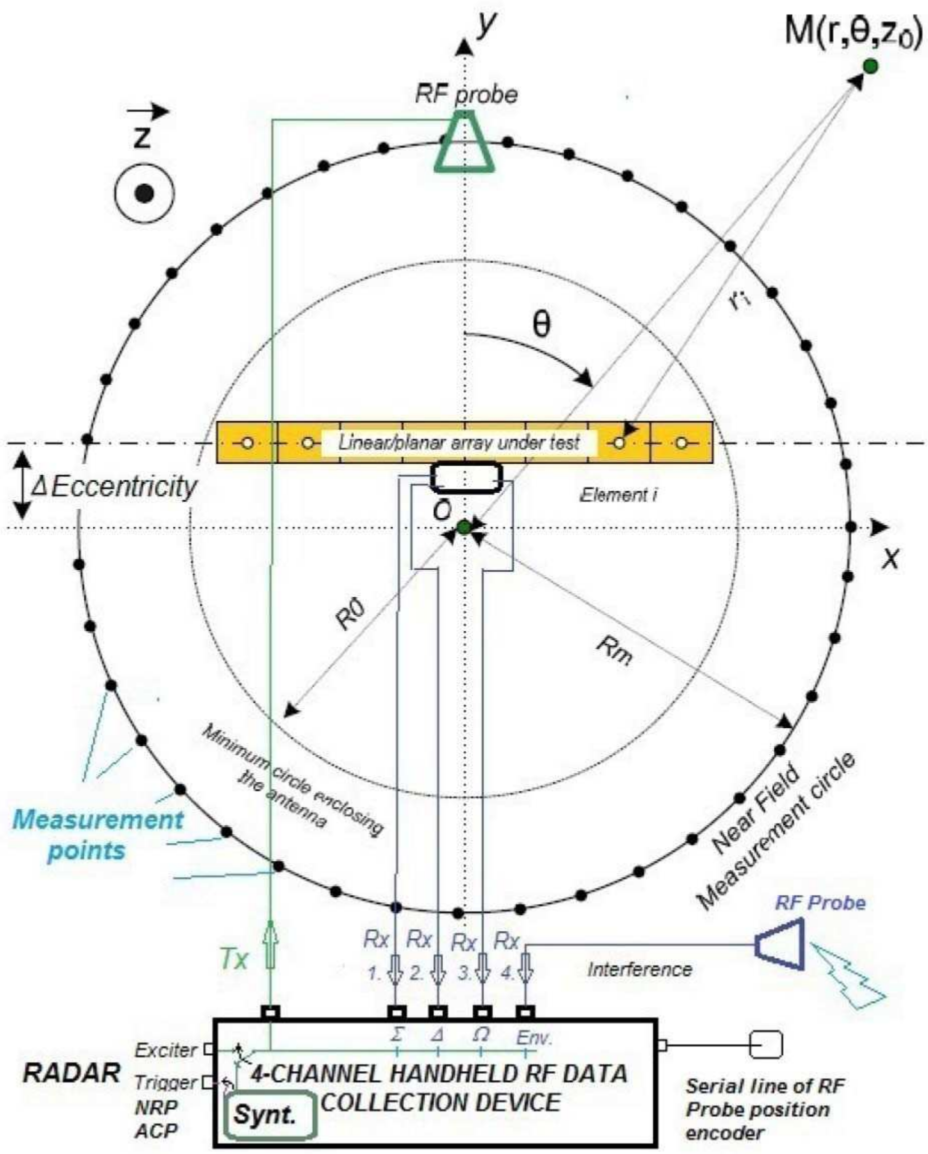


Fig 3 Typical SSR antenna measurement with a 4 channel VNA

The user-friendly GUI provides a wizard-style configuration, scoping the trigger and measured signals. Like every vector network analyzer, it has built in calibration. The GUI has an option for verbose commenting at every measurement start.

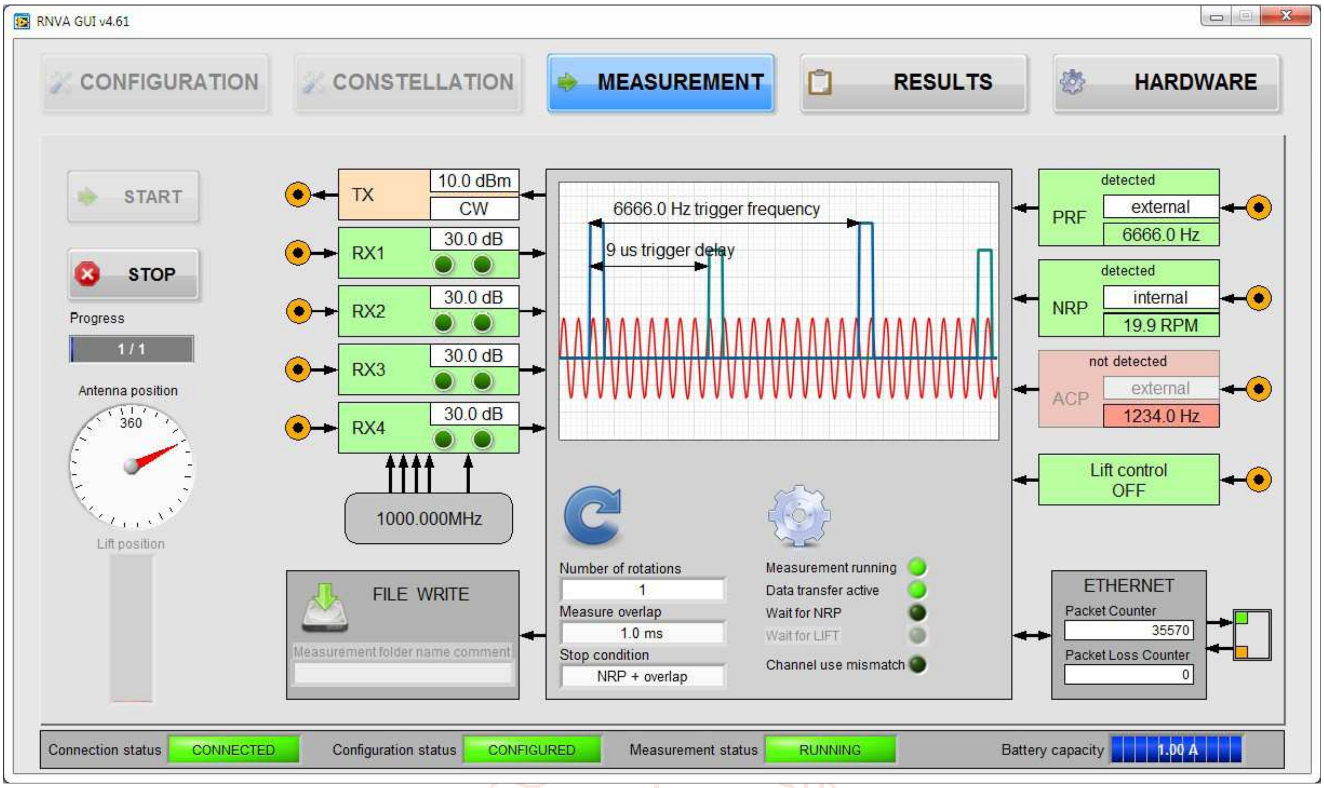


Fig 4 Control GUI

TABLE II GUIFUNCTIONS

Calibration	cables and internal RF paths
Configuration	through wizard; presets can be stored and reloaded
Trigger scope	PRF,NRP,ACP and RX envelope detectors
Measurement control	start, stop, triggered, free run
Measurement commenting	parameters, constellation, location, etc.
Active measurement	TX signal generated by the instrument
Passive measurement	reference signal can be coupled in at an RX port
Measurement monitoring	RAW data (amplitude and phase) can be monitored
Lift control	For cylindrical radiation pattern measurement an RF probe lifter can be remote controlled
Data export	into human readable format for easy post-processing with MATLAB or Excel

Related Research and Literature Survey

- In the Research part I have come across the few points which should be known before working on MCA: -
- Multichannel analyzer (MCA) is an important laboratory instrument which can measure distributions of input signals consisting of pulses. It operates in two different modes that is pulse height analyzer mode, and multichannel scaler mode.
- In pulse height mode, the input pulses are sorted into bins, basically it is a channel system, according to their amplitude, while in MCS mode they are sorted according to the time when they arrive. The MCA provides a graph spectrum display of the resulting distributions and can output the data to a printer or computer for further analysis. Control in older MCA's was done by hard-wired logic, whereas all modern MCAs are microprocessor-controlled and have fairly extensive local arithmetic operation capabilities.

V. RESULTS OF FIELDMEASUREMENTS

Measurements were carried out at DRDO premises. One of them is the ATC radar, it has a Raytheon Condor LVA type SSR antenna. During the recording the RF sensor was placed in the bore sight of the antenna beams, 7 meters from the antenna. The results shown in Fig 5. and Fig. 6. were generated from the measurements of the up-link frequency (1030 MHz). The field radiation pattern were calculated from the near filed measurements. The back projection of the field pattern was filtered by Kalman filter.

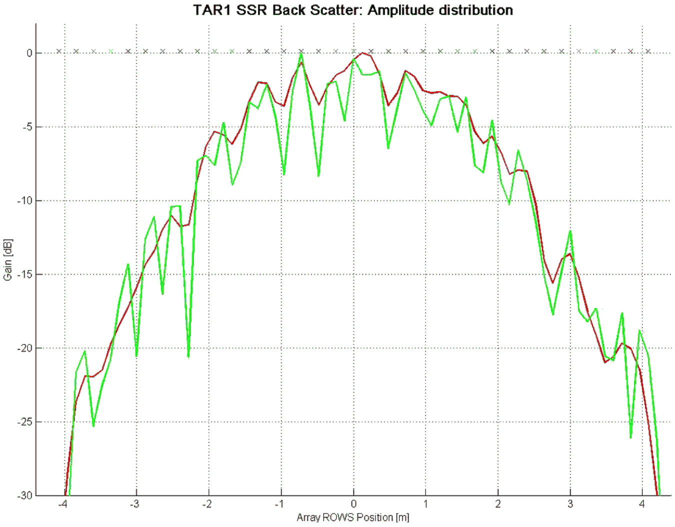


Fig 5 Central part of the SSR far field antenna patterns

From the aperture amplitude distribution (shown in Figure 5.) it was determined, that the columns #5, #8, #12, #15, and #23 are slightly degraded, which are responsible for higher side lobe levels.

The first test and the proof-of-concept measurements were carried out at TAR1 terminal approach radar located at Budapest Liszt Ferenc International Airport. After data collection of the TAR1's phased array in normal operational mode, the 13th radiating element (" row") was disconnected and the measurement repeated.

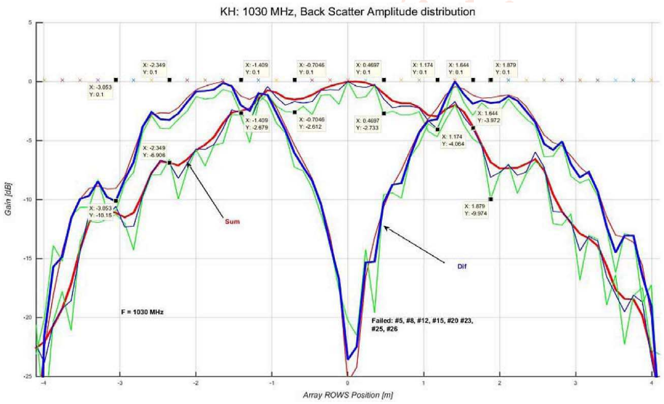


Fig 6 Calculated SSR antenna surface amplitude distribution [6]

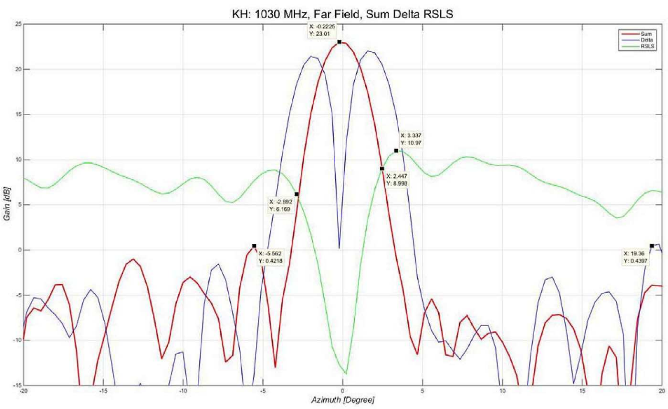


Fig 7 Calculated SSR antenna surface amplitude distribution

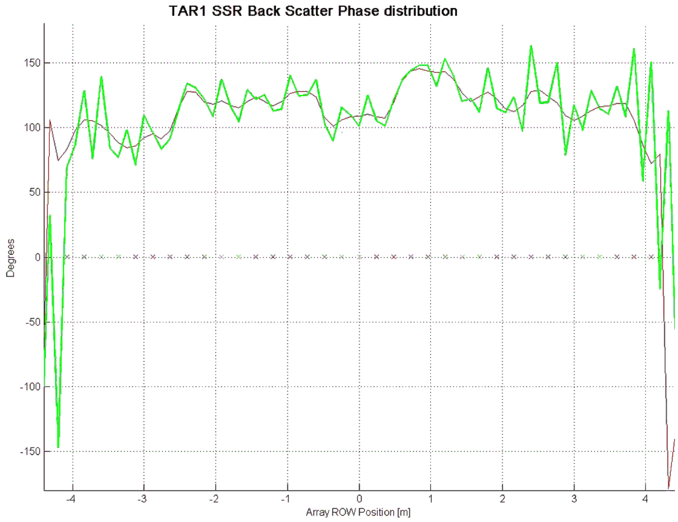


Fig 8 Calculated SSR antenna surface phase distribution

In Fig. 7. the normal amplitude distribution of the antenna is shown. The red line is the filtered result of the raw result (marked by the green line). In Fig. 8. the phase distribution of the antenna is shown, it is constant throughout the aperture, as expected. After the 13th row was disconnected, the amplitude distribution measurement was repeated.

VI. SUMMARY

The presented device and the near field measurement method provides an economical way to regularly check both primary and secondary radar antenna performances. They allow rapid measurement, while the outage time can be kept low. Overall, using the developed instrument, air traffic safety can be increased.

FUTURE SCOPE

To make a Multichannel Analyzer simulator to detect the radioactive activities.

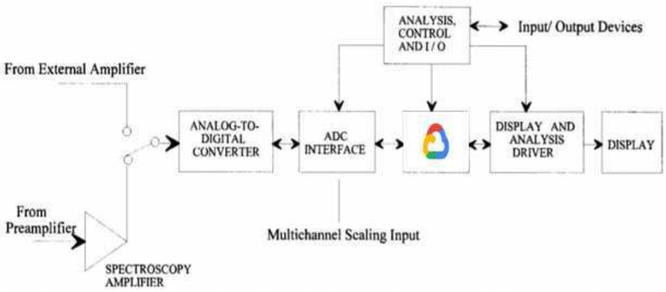
To manage the databases that we need to store using the own cloud generated storage which will not include the third-party involvement.

Program in such a way that It can also show the photopic in the spectrum.

Spectrum should follow ADC resolutions.

It should show ACTIVITY % [No. of disintegration per sec.]

DESIGN AND BLOCK DIAGRAM



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