Antenna pattern measurement using Field BITE Setup (Far Field)

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Abstract:
Any antenna can be successfully measured on either a near-field or far-field range, In general, far-field ranges are a better choice for lower frequency antennas and where simple pattern measurements are required, and near-field ranges are a better choice for higher frequency antennas and where complete pattern and polarization measurements are required. Once Radar antenna is tested in near field and Integrated in the Radar then Antenna pattern measurement for any reason is very difficult. Antenna pattern is very important factors for the passive Array Radars for detection and tracking and providing the absolute locations. A new procedure and test set up for Radar pattern measurement is discussed in this paper. The technique requires a custom Field BITE setup which receives 60MHz of radar signal and up converted to Radar frequency then radiated towards the Radar. By keeping BITE signal at fixed position (boresight) and steering the antenna electronically or mechanically in steps of 0.1 degree within coverage of the Radar. Receive BITE signal through antenna down converted to IF, digitize, process then log the data in terms of phase, amplitude strength and plot to know Antenna main lobe, Side lobe, mono pulse and then compared with previous NFTR data.

Key Words: Boresight, Field BITE, NFTR, Pattern, Far Field

I. INTRODUCTION

The purpose of Weapon Locating Radar is to detect the launch point of projectiles and to establish a segment of the trajectory of the projectile of sufficient length and positional accuracy to enable a computer to determine the location of the gun or launcher. Counter action may be then taken against the gun or launcher. This technique is known as back extrapolation because the computer follows back along the measured portion of the projectile path to the point where it intersects ground.

A phased array antenna is composed of lots of radiating elements each with a phase shifter. Beams are formed by shifting the phase of the signal emitted from each radiating element, to provide constructive/destructive interference so as to steer the beams in the desired direction. In the figure 1 (left) both radiating elements are fed with the same phase. The signal is amplified by constructive interference in the main direction. The beam sharpness is improved by the destructive interference.

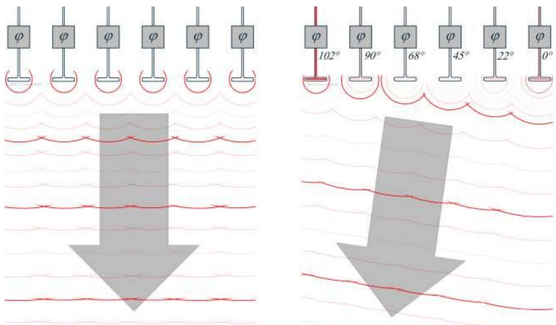

Figure1:electronic beam-deflection, left: Boresight, right: Deflected

Generally passive phase array antennas have following advantages.

- high gain and low side lobes
- Ability to permit the beam to jump from one target to the next in a few microseconds
- Ability to provide an agile beam under computer control
- arbitrarily modes of surveillance and tracking
- multifunction operation by emitting several beams simultaneously
- Graceful Degradation

In near field the antenna is collimated and antenna parameters like antenna gain, main lobe pattern, side lobe pattern, beam width and mono pulse pattern will be tested ref fig 2. The amplitude and phase of each element of a phased array can be determined accurately.

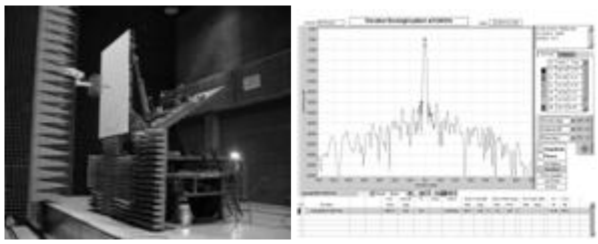

Fig2. NFTR setup with pattern

Once Antenna is tested and cleared in NFTR, the antenna will be mounted on Radar. Radar detects the target and locates a target's position by obtaining the target's 'range' and 'azimuth angle' and 'elevation angle' relative to a reference point on the antenna. The reference point typically used by radar systems in defining a target's position is the antenna 'boresight'. The target detection and accuracies are the important parameters which are function of antenna beam width. To demonstrate the antenna parameters for Narrow beam width and low side lobes far field antenna pattern measurement can be illustrated through Field BITE setup.

II. TEST SET UP FOR ANTENNA PATTERN MEASUREMENT

The Field BITE unit is basically a RF up converter. It receives the RF signal 60MHz from radar, up converted to radar frequency and radiated back to Radar. The set up shows radar vehicle, Field BITE vehicle and remote display is shown in Fig 3.

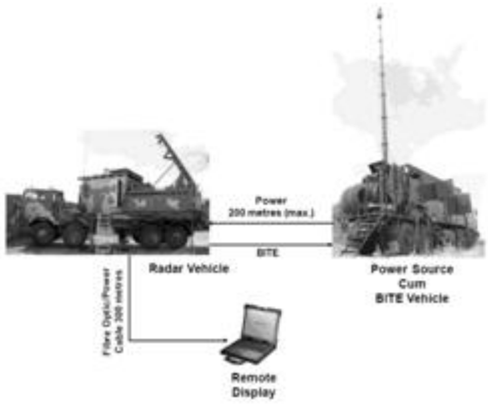

Fig.3. Field BITE measurement setup.

A. *The Range Equation*

When the Radar generates radar wave form and sent to field BITE unit via RF low loss cable and Radar computer controls radar and BITE frequency over RS 422 cable. The field BITE unit will generate C Band signal and radiates through a horn antenna, antenna is aligned towards radar antenna.

Distance between Radar antenna and field BITE antenna to proper beam formation Far-field distance determination: The mathematical expression for determining the minimum separation distance is:

$$R > 2D*D/\lambda$$

Where :R = Range length (separation distance between transmit and receive antennas)

D = Aperture of antenna under test

λ = Measurement wavelength (shortest of the ones tested)

where,

BITE Horn radiates a power P_{t_BITE} from its antenna of gain G_{Horn}, the power density P_d at range R, where the horn is placed is given by 1.

Pd=(Pt_BITE *Gt_BITE)/(4*Pi*R*R) --------- 1

The receive antenna of Radar (gain = G_{Radar}) capture a portion of the transmit energy incident on it. The receive signal power shown in Equation 2.

Pr_radar= Pt _BITE*G radar*Ae/(4*Pi*R*R) ----2

where,

A_e = effective aperture of BITE receive antenna = $(G_{radar}\,\lambda^2 / 4\,\pi)$

λ = wavelength

The retransmitted power level from the BITE is adjusted by a digital attenuator so that the received power at Radar is well within its dynamic range.

B. *The Field BITE Circuitry*

The circuitry of Field BITE unit is designed to ensure minimum input power requirements of Radar and the BITE unit. Amplification, up-conversion and DDS control are provided accordingly. The block diagram of the key components is shown in Fig.4.

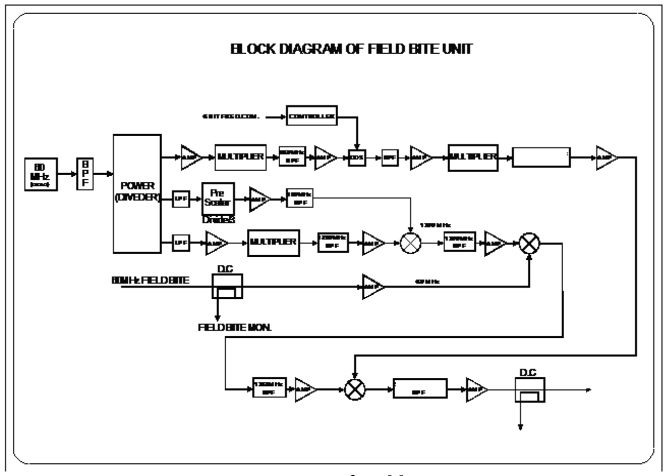

Fig.4. Key components of Field BITE unit.

III. ANTENNA PPATTERN MEASUREMENT PROCEDURE

PREREQUISITES:

The key consideration in designing a far-field range is to simulate the operating environment of the test antenna as closely as possible. Far-field measurements can be performed on outdoor ranges.

The selection of an appropriate test range is dependent on many factors such as:

- Availability, access, and cost of real estate suitable for quality measurements
- Weather
- Budget
- Security considerations
- Test frequency and aperture size
- Antenna handling requirements

By considering above parameters Radar set up can be made to measure antenna pattern using field BITE set up. BITE is kept at max elevation. Antenna pattern is taken in 2 steps.

- Keeping elevation constant and scanning in azimuth, antenna pattern for azimuth is taken.
- Keeping azimuth constant and scanning in elevation, antenna pattern for elevation is taken.

1. Radar set up can be made at open space where there are no obstructions in front of the antenna (El above 2 deg.).The field BITE Mast is erected in front of the antenna at a distance of more than 120 meters (3). Antenna and field BITE Horn should be in Line of Sight or approximately aligned at radar bore sight. Ensuring Field BITE horn kept at maximum height (above 5 deg of radar angle).

$$d = 2\,D^2/\lambda, \text{ -------------------------------- } 3$$

2. Switch ON the radar and check system MDS is of desired value for all the spot frequencies. The Field BITE signal radiated from Horn will be received and accuracies will be measured on C-scope of Display for 0.1° in Az and El.

The Path Loss (4) between Radar and Field BITE unit is 90dB.

$$P = (4\pi d/\lambda)^2 \;, d = \text{distance}, \lambda = c/f \text{ ,----- } 4$$

3. The field BITE signal strength will be attenuated such that the BITE signal strength should not saturate the radar. Since Radar Saturates at – 60dBm at LNA input, the received power should be lesser than this value and greater than System MDS (5).

$$Pr = Pt\_BITE(dB)+Gt\_BITE(dB)+Gr\_radar(dB)-20\log(4\pi d/\lambda). \text{ –––- } 5$$

$$= -60 \text{ dB} + 15\text{dB} + 35\text{dB} - 90\text{dB} = -100 \text{ dB} = -70\text{dBm}$$

4. The Radar INU will determine the heading and in turn the position of Field BITE horn.

Fig.5. Field BITE Setup

5. A single beam is put at horn position after the exact position of Horn is determined by this process.

6. In order to achieve a full scan pattern, the System computer was programmed with special set of instruction to sweep the beam at a step of 0.1° in both azimuth and elevation and the same was logged onto the computer for 3 to 4 scans respectively. The scan angle was at ±10° w.r.t the horn necessitating the entire antenna pattern coverage for monitoring various antenna parameters.

7. The data logged at different spot frequencies for both Azimuth and Elevation was plotted to observe the antenna parameters and compared with NFTR data. It should be 25dB down with respect to main lobe.

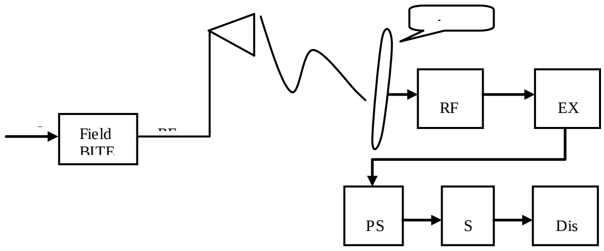

Fig.5. Radar and BITE main sub-systems

V. CONCLUSIONS

Based on this procedure the side lobe measurement is carried out and the results were matching with NFTR data. All the frequency spots are tested with Azimuth and Elevation channels and the same procedure is extended for mono pulse measurements.

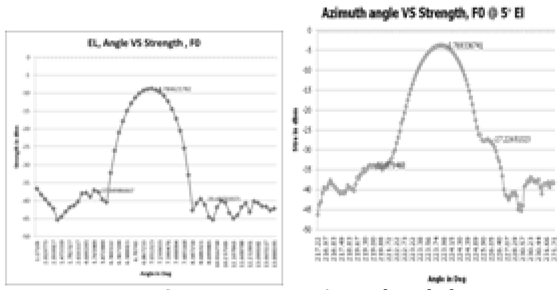

Fig.6. Beam Patten in Azimuth and Elevation

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