How to Interpret Reader Antenna's Radiation pattern - A guide for RAIN RFID Systems Integrators

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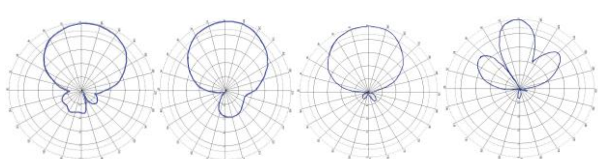
***Abstract*— Systems integrators often struggle to understand and interpret radiation patterns of reader antennas to set up RFID read points to efficiently detect intended tags and avoid reading unwanted or stray tags. This poster presents a guide to make RFID deployments easier.**

Keywords—UHF RFID, RFID reader antennas, radiation, stray reads, read point, half-power beamwidth.

I. Reader Antenna's Radiation Patterns

An antenna's radiation pattern is a graphical representation of the antenna's radiated power in a three-dimensional space at far-field distances [1]. The radiation pattern will not change with distance in the far-field. It can be plotted in two-dimensional spherical coordinates as slices in azimuth and elevation planes using a polar chart. Times-7 antenna's [2] radiation patterns are shown in Fig. 1. Antennas follow the principle of reciprocity, and thus, the radiation pattern holds for both transmitting and receiving antennas. The maximum directive gain of an antenna lies within the peak of the main lobe radiation. Side lobes are minor lobes found on the sides of the main lobe. Their magnitude is lower compared to the main lobe. The back lobe is also a side lobe that is 180° opposite to the main lobe. The ratio between the magnitude of the main lobe and the back lobe is known as the antenna's front-to-back ratio (FBR).



(a) (b) (c) (d)

Fig.1 Radiation patterns: (a) A5010 Elevation YZ, (b) A5010 Azimuth XZ, (c) A5060 Elevation YZ and (d) A5060 Azimuth XZ.

The antenna's radiation angle or the width of the beam is termed as the beamwidth. Half Power Beamwidth (HPBW) angle is calculated between the half-power (3dB) points of the main lobe [1]. Wide beam antennas are low gain in nature compared to narrow beam antennas that have higher gain. The antenna's radiation pattern can be symmetrical or asymmetrical in both azimuth and elevation planes. Rectangular arrays usually have asymmetric HPBWs in elevation and azimuth planes. The magnitude of the back lobe is inversely proportional to the size of the ground plane or the reflector. A reader antenna's radiation pattern determines the ability to detect tags in a given volume.

II. Determination of Theoretical Read Zone

Theoretically, the antenna's RF coverage can be determined for a specific distance with the HPBW angle. The beam angle represents two right-angled triangles (see Fig.2) with two hypotenuses, two adjacent sides, and one opposite side. Using trigonometry, equation (1) is formulated to determine the RF read zone. Theoretical read zones for commercial antennas in both planes are shown in Table I for 2.4 m height.

$$\text{RF read zone} = 2 \times \left(\text{H} \times \tan\left(\frac{\phi}{2}\right)\right) \tag{1}$$

Where, ϕ *= HPBW and H = Height*

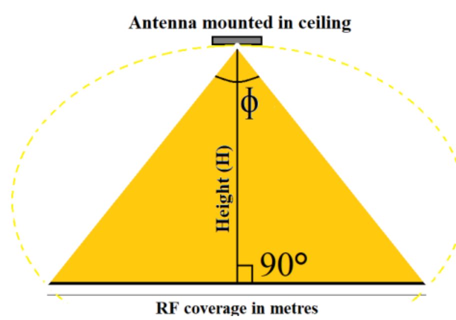


Fig.2 Theoretical read coverage determination

TABLE I. Read Zone Estimation for Commercial Antennas

Commercial Antenna Model Number	Elevation (YZ Plane)		Azimuth (XZ Plane)	
	HPBW	~Read Zone	HPBW	~ Read Zone
Times-7 A5010	68°	3.2 m	68°	3.2 m
Times-7 A5020	~100°	5.7 m	~100°	5.7 m
Times-7 A5060	25°	1 m	60°	2.7 m
Keonn P-11	110°	6.9 m	110°	6.9 m
Keonn P-12	60°	2.7 m	90°	4.8 m
Keonn P-13	40°	1.7 m	90°	4.8 m
Laird S9028PCL	70°	3.3 m	70°	3.3 m
Laird S9025PR	100°	5.7 m	100°	5.7 m
MTI 262006RH	63°	2.9 m	63°	2.9 m
MTI 263020RH	30°	1.3 m	63°	2.9 m

III. RFID Read Zone

Although RF read zones estimated in Table I using Eqn. (1) is encouraging, it is not quite suitable for RFID coverage estimation due to its dependencies on the reader power setting, cable losses, tag's sensitivity, tag antenna's radiation pattern, and multi-path reflections caused by the environment [1]. For this experiment, the RFID read zone is mapped on A5010 and A5060 antennas by moving an Avery Dennison AD-237 Monza-R6P tag [3] in 100 mm steps along their boresight's elevation and azimuth axis to plot the *maximum* read distance Fig.3 shows the measurement setup consisting of the antenna under test, tag held by a Styrofoam carrier and a medium density fiber (MDF) board with 100 mm guide holes. An Impinj r420 reader [4] is operated in 902 to 928 MHz frequency band with its default settings at 10 dBm transmit power and -80 dBm RSSI (receive signal strength indicator). Mapped read zones shown in Fig.4 conform with the radiation patterns of respective antennas shown in Fig.1. The coarse plot could be improved by increasing the measurement resolution to 20- or 10-mm steps.

The mapped read zone logarithmically expands when the antenna's input power is varied. For instance, at the boresight, the A5020's maximum read distance of 800 mm would probably increase up to > 8m at 30 dBm. It is noted that the RF span does not match with calculated values shown in Table I for the same reasons such as reader power, tag's sensitivity, tag antenna's radiation pattern, and so on. It is also noted that the A5010 antenna with 68° HPBW in the elevation plane yielded only a 500 mm span, while the A5060 produces an 800 mm span with only 60° HPBW in the same plane. This should not be misunderstood as a wide HPBW yields a narrow RFID read zone. The following section explains the reason behind this interesting result.

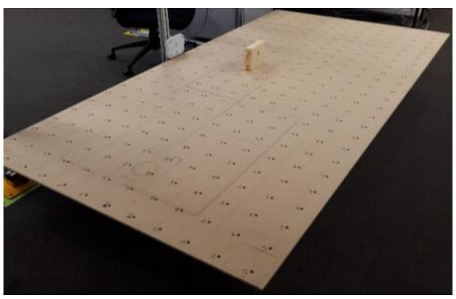
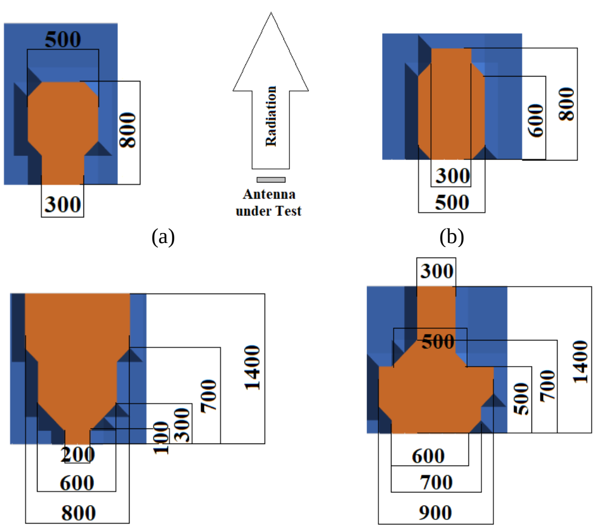


Fig.3 RFID Read Zone Measurement Setup



(a) (b) (c) (d)

Fig.4 Measured Read zones (in mm): (a) A5010 elevation-YZ, (b) A5010 azimuth-XZ, (c) A5060 elevation-YZ and (d) A5060 azimuth-XZ.

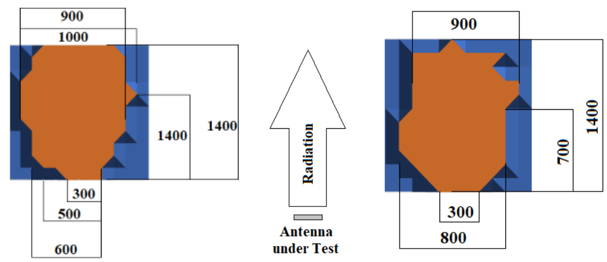
IV. EFFECTIVE ISOTROPIC RADIATED POWER

Effective Isotropic Radiated Power (EIRP) is the total power radiated by an isotropic antenna in a single direction [5]. EIRP for any antenna can be calculated using Eqn. (2). EIRP for different antennas with different gain would be different, and this is the reason behind the interesting result in the previous section.

$$\mathrm{EIRP\ (dBm)} = P_T\,\mathrm{(dBm)} - L_C\,\mathrm{(dB)} + G_A\,\mathrm{(dBi)} \qquad (2)$$

Where P_T = *Transmit power,* L_C = Cable losses, *and* G_A = *Antenna gain*

Calculated EIRP for the A5010 antenna (5 dBi gain) with 0.5 dB cable loss at 10 dBm reader power is 14.5 dB while the EIRP for the A5060 antenna (7.5 dBi gain) with the same reader power and cable losses is 17 dBm. A5060's EIRP is higher than A5010, and thus, the RF span for a 68° HPBW appears to be smaller than the 60° HPBW. The transmit power for the A5010 antenna is increased to 12.5 dBm to match the A5060's EIRP, and the RF read zone is remeasured in both planes. Measurements at the same EIRP shown in Fig. 5 reveals that the 68° HPBW yields a wider RF span compared to 60° HPBW.



(a) (b)

Fig.5 Measured Read zones at 17 dBm EIRP (in mm): (a) A5010 elevation-YZ and (b) A5010 azimuth-XZ.

To make RFID deployments easier, systems integrators should investigate key antenna parameters such as gain, polarization, and HPBW and do a theoretical calculation shown in section II to get an idea about the read coverages. Based on the site visit, should there be a stray tag-read concern, they must opt for narrow beam antennas. Once the antenna is selected, a test like the one mentioned in section III must be performed with an RFID tag that is intended to use. Test results will be accurate if tags are not tested in free space but with tagged assets. Reader's transmit power and receive sensitivity filter settings can be fine-tuned to map the intended read zone.

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