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Evaluating the Antenna Performance of 802.11n Wireless Routers in an Indoor Environment

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Abstract

The antenna performance of three 2x2 802.11n wireless routers is assessed at 2.4GHz using a laptop as a reference client. The analysis combines in-situ measured 3D radiation patterns with state-of-the-art 3D ray-tracing for a number of different client locations and access-point/client orientations in a typical three-floor home.

A router employing two PIFAs achieves the highest average signal level on the top floors (3-10dB better); a router with two external dipoles on the same floor level (1-5dB better); and a router with two patches is in-between and results in the largest signal variations (5-15dB larger dynamic range).

Results also demonstrate the importance of measuring 3D radiation patterns of all the individual elements of a MIMO system in-situ and not just a single element in isolation.

Antenna Radiation Patterns

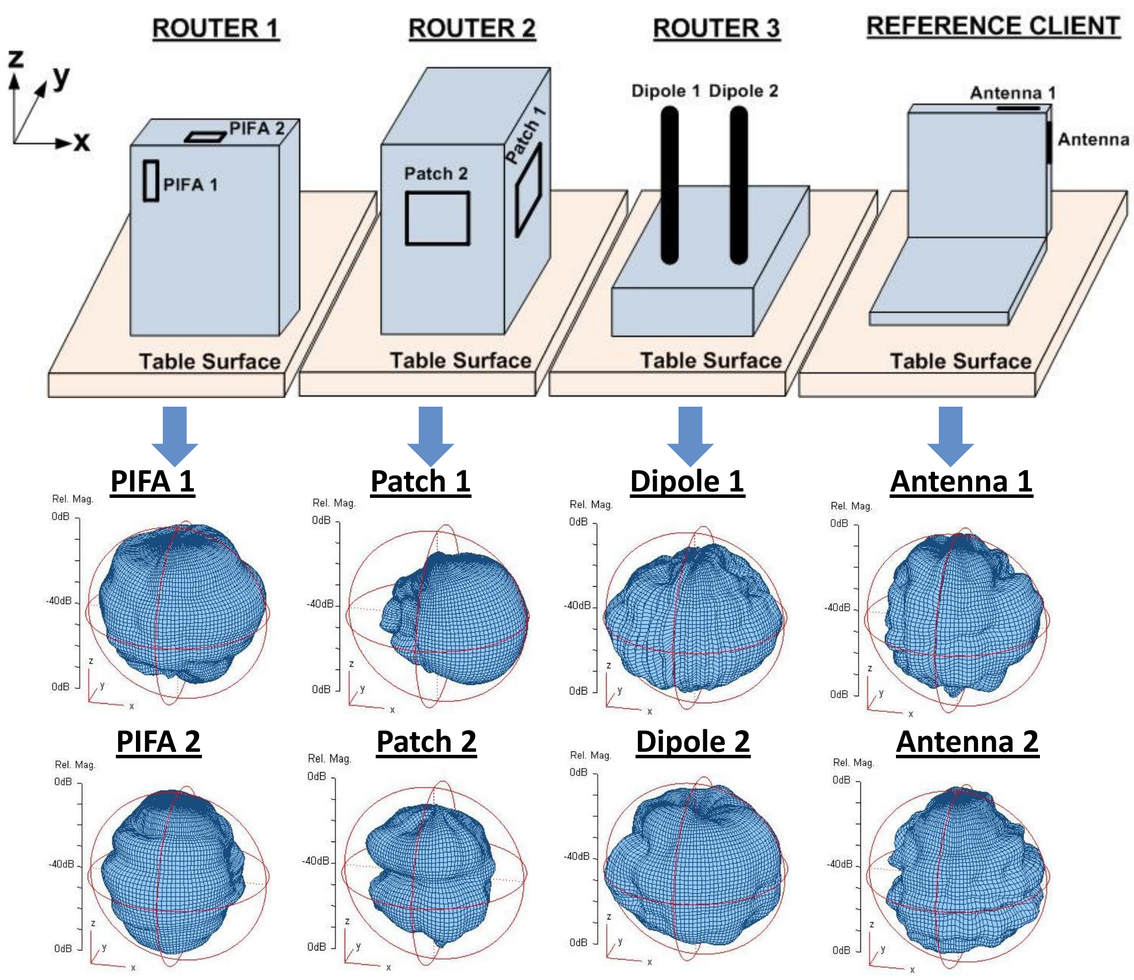

Fig. 1: Routers and laptop client antenna configurations and total power radiation patterns (measured at 2440 MHz in the anechoic chamber).

Element	Power in Polarisation (%)		Maximum Directivity (dBi)	
	Vertical	Horizontal	Vertical	Horizontal
PIFA 1	49	51	5.0	3.9
PIFA 2	23	77	4.5	6.4
Patch 1	95	5	7.6	-3.6
Patch 2	14	76	3.4	11.2
Dipole 1	94	6	4.9	-3.1
Dipole 2	90	10	5.0	-1.4
Laptop antenna 1	51	49	4.8	5.0
Laptop antenna 2	65	35	5.8	3.4

Table 1: Radiation patterns statistics

- The 3D radiation patterns allow a full insight into the behaviour of the antenna system that is not possible to deduce from single planes (e.g. x-y, x-z, y-z).
- The patterns of all the individual antennas of a MIMO system should be measured in-situ and not just a single element in isolation, as identical elements produce significantly different patterns and directivities.

Propagation Environment

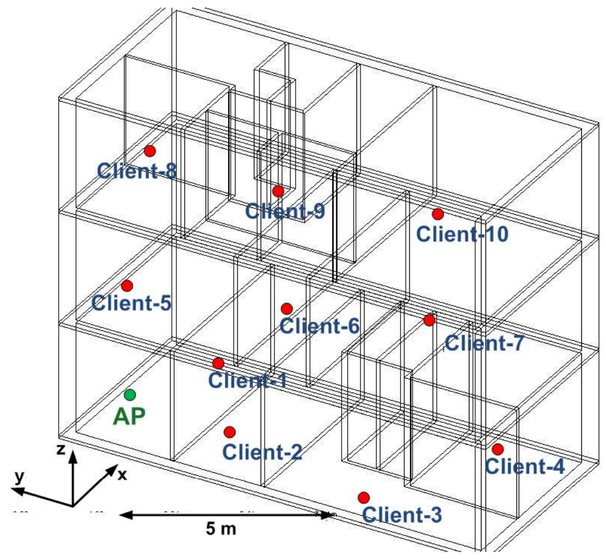

Fig. 2: Indoor environment with AP and client locations.

- Spatial and temporal multipath components modelled with a 3D indoor ray-tracer (analysis performed at 2.4GHz with 12dBm transmit power per radio chain).
- Typical three-floor home with AP location fixed on ground floor and ten client locations distributed around the property.
- AP rotated in azimuth over 360°; Client tilted in elevation between 0° and 40°, and rotated in azimuth over 360°.
- Received signal strength at the client computed at each location for each antenna-to-antenna link, AP rotation, and client tilt and rotation.

Results

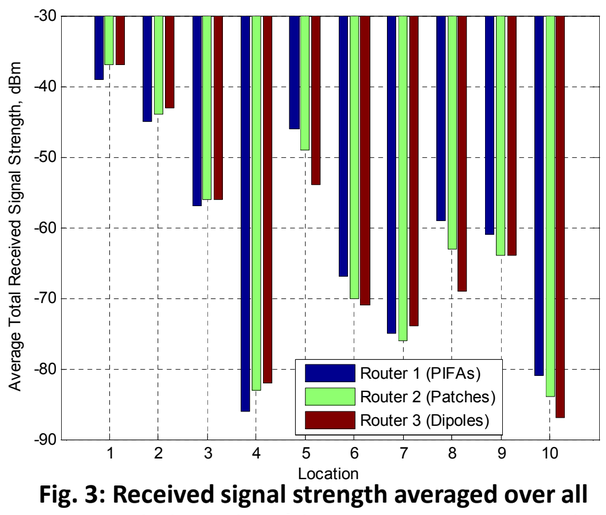

Fig. 3: Received signal strength averaged over all antenna links and AP/client orientations at each location.

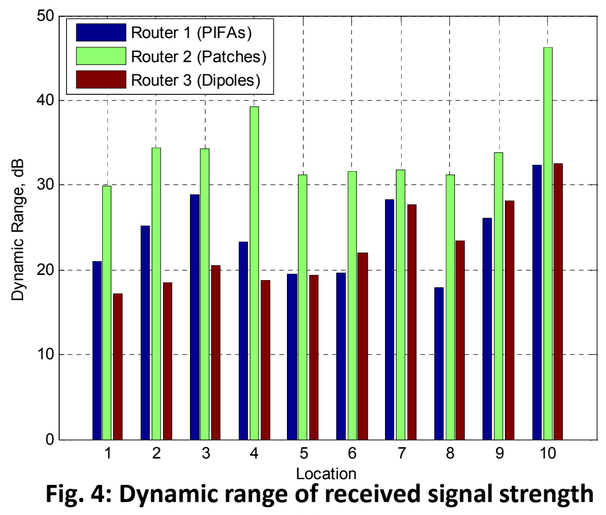

Fig. 4: Dynamic range of received signal strength at each location.

- On the same floor level, router 3 results in the highest average signal level, whereas router 1 in the lowest (1-5dB difference).
- Router 1 transmits the highest signal in average to almost all the top floors locations, where router 3 has the worst performance (3-10dB difference). The only exception is location 7, where dipoles perform better.
- The average performance of router 2 is in almost all cases in-between the other two.
- Routers 1 and 3 result in a dynamic range (i.e. difference between maximum and minimum) between 17dB and 32dB. This shows that even with routers with omni-directional antennas, the performance is sensitive to the AP/client orientation.
- The dynamic range of router 2 is 5-15dB higher than the other two, as it is more sensitive to orientation due to the directional radiation of the patches.

Conclusions

- A router employing two PIFAs achieves the highest average signal level on the top floors (3-10dB better); a router with two external dipoles on the same floor level (1-5dB better); and a router with two patches is in-between and results in the largest signal variations (5-15dB larger dynamic range).
- Results demonstrated the importance of measuring 3D radiation patterns of all the individual elements of a MIMO system in-situ. Antennas must be designed for a communication system accounting for the effect that the application will have on their performance. It is important not just to measure a single element in isolation.
- Future work will combine the RF-level results with an 802.11n simulator to predict the impact of the antennas on the system-level performance, accounting for the various modulation and coding schemes and the different MIMO transmission techniques (e.g. spatial-multiplexing or eigen-beamforming) of the 802.11n standard.

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