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Antenna Types for Small Cells Base Stations

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Abstract: ***SBS are the expected approach in achieving 5G targets. Indeed, reducing cell sizes through the use of heterogeneous networks (HetNets), employing greater spectral efficiency at each BS and, an increase an in spectrum are seen as solutions to meet the requirements of future wireless networks. These fall under the category of ``network densification'', provided by spatial densification and spectral aggregation. Spatial densification is achieved by increasing the number of antennas at the SBS and increasing the density of SBSs per m2.Antennas requirements will be crucial in spatial densification in achieving 5G requirements.***

Keywords: SBS, 5G, Antenna types

1. Introduction

The recent advancement of wireless networks have seen a change from traditional macro cell base stations (MBSs) covering a wide areas e.g. 10s of kilometres, to the introduction of much smaller footprint small cell base stations (SBSs). These typically include pico-cells, femto cells, and ultra-dense small cells covering 100s to 10s of meters. Furthermore, it is widely agreed that increasing the number of cells with small radii will be the main contributor of the next generation cellular system (i.e. 5G) to increase the network capacity and to provide required data rates. Hence, SBS are the expected approach in achieving 5G targets. Indeed, reducing cell sizes through the use of heterogeneous networks (HetNets), employing greater spectral efficiency at each BS and, an increase an in spectrum are seen as solutions to meet the requirements of future wireless networks [1], [2]. These fall under the category of ``network densification'', provided by spatial densification and spectral aggregation [2]. Spatial densification is achieved by increasing the number of antennas at the SBS and increasing the density of SBSs per m2.

The paper is organized as follows - Section 2 discusses various antenna types used in small base station , Section III provides a discussion into recent research surrounding the use of multiple antennas in current generation SBSs to overcome interference problems in HetNets.

2. Antenna types used in SBS

2.1 Small Antenna types:

In first generation SBSs, the antenna system is of a static nature. Usually such installations use simple dipoles or printed circuit board antennas (PCB-antenna) with low gain and rather omni-directional, fixed patterns commonly termed as small antenna types [3]. The most popular and efficient small antenna types:

¼ Wave Whip (Monopole)

A whip antenna provides exceptional overall performance and stability, has an isotropic pattern, a wide bandwidth, it is cheap and it is easily designed. Since a full-wave or even a half-wave dipole whip is generally quite long, most whips are ¼ wave. Note: If one branch of the dipole antenna is replaced by an infinitely (enough) large ground plane, due to the effect of mirroring, the radiation pattern above the ground plane remains unaffected and delivers practically quite the same performance of a whole half-wave dipole. This simple and most effective small antenna is also called a quarter-wave monopole and is the most common antenna on today's portable devices. Since most devices have a circuit board anyway, using it for half of the antenna can make a lot of sense. Generally, this half of the antenna will be connected to ground and the transmitter or receiver will reference it accordingly.

Helical

A helical element is a wire coil usually wound from copper, brass, steel or can be even realized on PCB. Compared to the monopole, which is essentially a two-dimensional structure, the helical antenna is a 3-dimensional structure but is nothing else as a "shorter quarter wave". Its radiation pattern is similar in nature to the monopole. This provides an optimum condition for portable communications. A small helical significantly reduces the needed physical size of the antenna and that is important at lower frequency (larger antennas); however this reduction is not without a price. Because a helical has a higher Q factor, its bandwidth is narrower and its ideal gain is as a matter of principle lower than a "full size" quarter-wave whip. In many cases, the helical antenna will perform as well as the elongated ¼ wave antenna. The distributed capacity of the helical ¼ wave antenna acts as an impedance matching section that is not present in the full size ¼ wave antenna and minimizes the effect of the underground.

PCB antenna

PCB antenna is nothing else as a "special ¼ wave whip" antenna where the whip is realized as copper trace on a PCB board. A PCB antenna is stable, reproducible, easy to manufacture and uses the existing board.

Table 1: Short antenna comparison

Antenna	Pros	Cons
¼ Whip antenna	Low cost solution, good efficiency, good radio performance, modular approval possible, simple to integrate	Large at lower frequency (whip length and ground plane), may need manual shape fastening (especially for 315 MHz)
Helical	Good efficiency, small, very good overall compromise for 315	Higher costs as Whip. Matching network design needed.

	MHz (size and performance)	
Chip	Smallest solution of 868 MHz antenna.	High price. Matching network design needed. For 315 MHz no chip antennas with good efficiency known yet, recommended only in special cases (reduced range requirements and limited place availability, e.g. for key fob).
PCB	Lowest cost solution, reproducible, stable, use of existing PCB	For 315 MHz only recommended if PCB is large enough (incl. spacing).

2.2 Dipole types

The dipole antenna consists of two conductive elements such as metal wires or rods which are fed by a signal source or feed energy that has been picked up to a receiver[24]. The energy may be transferred to and from the dipole antenna either directly straight into a from the electronic instrument, or it may be transferred some distance using a feeder. This leaves considerable room for a variety of different antenna formats.

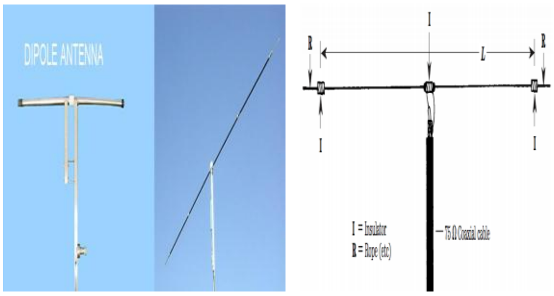

Figure 1: Typical Dipole antenna

Although the dipole antenna is often though in its half wave format, there are nevertheless many forms of the antenna that can be used.

Half wave dipole antenna: The half wave dipole antenna is the one that is most widely used. Being half a wavelength long it is a resonant antenna.

Multiple half waves dipole antenna: It is possible to utilize a dipole antenna or aerial that is an odd multiple of half wavelengths long.

Folded dipole antenna: As the name implies this form of the dipole aerial or dipole antenna is folded back on itself. While still retaining the length between the ends of half a wavelength, an additional length of conductor effectively connects the two ends together. Read more about the Folded-dipole

Short dipole: A short dipole antenna is one where the length is much shorter than that of half a wavelength. Where a dipole antenna is shorter than half a wavelength, the feed impedance starts to rise and its response is less dependent upon frequency changes. Its length also becomes smaller and this has many advantages. It is found that the current profile of the antenna approximately a triangular distribution. Read more about the Short-dipole.

Non-resonant dipole: A dipole antenna may be operated away from its resonant frequency and fed with a high impedance feeder. This enables it to operate over a much wider bandwidth.

2.3 Microstrip patch antenna

The use of multiple antennas in SBSs face several challenges such as complexity, increased signal processing, cost and physical limitations associated with the form factor of small cell housings [8], [9]. Microstrip patch antennas are generally chosen as the technology for diversity antennas for both mobile BSs and terminals because of its advantages of compactness and easy fabrication [12], [13]. Patch antennas are a form of microstrip antenna based upon printed circuit board (PCB) technology to create _at radiating structures on top of dielectric, ground plane backed structures [14]. These have suitability for SBSs because of their low cost and high reliability. Microstrip patch antennas are widely used in the microwave frequency region because of their simplicity and compatibility with printed-circuit technology, making them easy to manufacture either as stand-alone elements or as elements of arrays. The advantages of microstrip antennas make them suitable for various applications like, vehicle based satellite link antennas [2], global positioning systems (GPS) [22], radar for missiles and telemetry [21] and mobile handheld radios or communication devices [3]. In its simplest form a microstrip patch antenna consists of a patch of metal, generally rectangular or circular (though other shapes are sometimes used) on top of a grounded substrate [23]

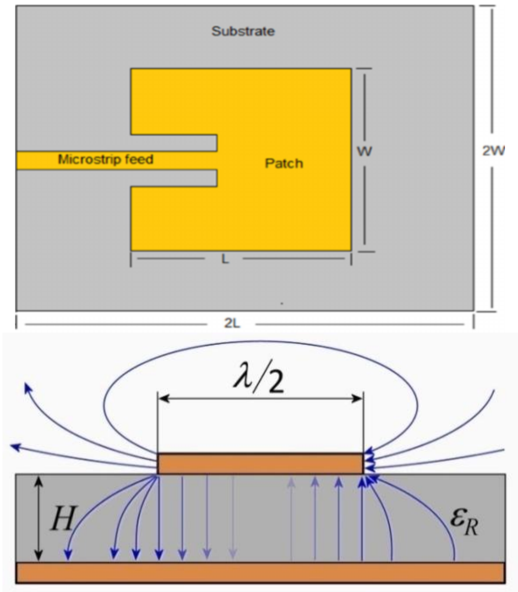

Figure 2: Typical Patch antenna

Table 2: Comparison of various performance parameters of different patches of microstrip antenna [2]

Sl. No.	Shape of Patch	Return loss vs. frequency	Gain (dB)	Lower cut off frequency (GHz)	Higher cut off frequency (GHz)	Band width (GHz)
1.	Circle (Radius: 30)	16.50	8.1756	6.80	7.43	0.63
2.	Rectang	-19	6.7619	7.33	8.47	1.14

	ular (60, 50, 0)					
3	Ellipse (Major Axis:20, Ratio:2)	-25	7.2326	6.90	7.96	1.06
4	Pentagon (Side: 44.36mm)	-23	9.0943	7.30	8.54	1.24
5	Hexagon (Side: 35mm)	-22	7.4406	7.30	8.52	1.22
6	Square (60, 60, 0)	-21	8.2799	6.53	7.45	0.92

2.4 Planar inverted –F antenna

The use of planar inverted-F (PIFA) antennas are another form of microstrip antenna which are popular in mobile phone/UE technology because they are resonant at l/4 λ [15], where λ is the wavelength corresponding to the frequency of operation. They are therefore attractive in terms of their physical properties, which makes them equally suitable for SBSs.

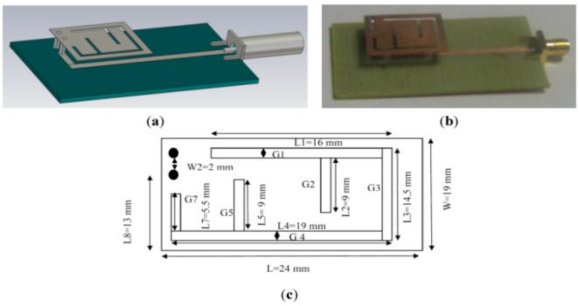

Figure 3: Typical PIFA antenna

2.5 E-plane horn antenna

The use of E-plane horn antennas, a physically flared (in the direction of the electric E field) antenna which is a natural evolution of the idea that any antenna represents a region of transition between guided and propagating waves [14], have also found use in SBSs applications [16]. E-plane horns offer moderate directivity and since they do not have any resonant elements they can operate over a wide range of frequencies.

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Table 3: Comparison of Small base station antennas

Type	Typical Features	Bandwidth
PCB dipole	Low cost. Low profile, Omnidirectional	The center frequency for the thinnest dipole is 1.82 GHz, the 5mm width dipole is centered at 1.74 GHz, and the 10mm wide dipole has a center frequency of 1.65 GHz.
Microstrip Patch[14]	Low cost. Low profile, Easy to fabricate ,Resonant at l/2 λ	5.58 GHz.
PIFA[10][11][13][15]	Low profile, Resonant at l/4 λ, Physically small	3.1–10.6 GHz
E-plane [17][18][19][20]	Moderate directivity , High Bandwidth	UHF and microwave frequencies, above 300 MHz.

3. Advanced Antenna Technologies

3.1 Latest trends in SBS Technology

In line with enhancing the small cell layer with more powerful and flexible SBSs, multi-standard SBSs are now being offered by small cell providers. As an example NTT DOCOMO's Xi FBS [21] is capable of both 3G (W-CDMA) and 4G (LTE). SISO downlink/uplink rates of 14Mbps and 384kbps for its 3G mode and downlink/uplink rates of 112.5/37.5 for its 4G mode are supported. Further developments are likely to see additional antenna elements and higher order modulation schemes to further improve the data rates. Airspan, a leading provider of LTE SBSs, recently demonstrated the use of it's, so called, lightweight-CoMP technology in the 3.5GHz band [22]. This showed how a cluster of SBSs can operate in a single radio cluster with joint transmission to improve the outdoor and indoor coverage, network capacity and the quality of user experience of a rooftop MBS deployment. Beam forming, using a six-element array is used in Apple's Airport device [21]. This is a Wi-Fi router product operating at 2.4GHz and 5GHz but nonetheless illustrates use of advanced antenna techniques in a small form factor similar to a FBS. Additional techniques to address capacity such as multi-carrier and carrier aggregation will push data rates yet further but will eventually reach the limits of the technology and resources.

References

[1] A. Ghosh *et al.*, “Millimeter-wave enhanced local area systems: A high data- rate approach for future wireless networks," *IEEE J. Sel. Areas Communication.*, vol. 32, no. 6, pp. 1152_1163, Jun. 2014.

[2] N.Bhushan et al., ``Network densification: The dominant theme for wireless evolution into 5G," IEEE Communication. Mag., vol. 52, no. 2, pp. 82_89, Feb. 2014.

[3] H. Claussen, L. T.W. Ho, and L. G. Samuel, ``An overview of the femtocell concept," Bell Labs Tech. J., vol. 13, no. 1, pp. 221_245, 2008

[4] L. Ndikumasabo, ``MIMO antenna configuration for femtocell application," in Proc. Loughborough Antennas Propagation. Conf. (LAPC), Nov. 2009, pp. 125_128.

[5] Y. Gao, X. Chen, and C. G. Parini, ``Channel capacity of dual-element modified PIFA array on small mobile terminal," Electron. Lett., vol. 43, no. 20, pp. 1060_1062, Sep. 2007

[6] H. Claussen, L. T.W. Ho, and L. G. Samuel, ``An overview of the femtocell concept," Bell Labs Tech. J., vol. 13, no. 1, pp. 221_245, 2008.

[7] Y. Gao, X. Chen, Z. Ying, and C. Parini, ``Design and performance investigation of a dual-element PIFA array

at 2.5 GHz for MIMO terminal," IEEETrans. Antennas Propagation., vol. 55, no. 12, pp. 3433_3441, Dec. 2007.

[8] S. Yang and K. Luk, ``Design of a wide-band L-probe patch antenna for pattern reconfiguration or diversity applications," IEEE Trans. Antennas Propagation., vol. 54, no. 2, pp. 433_438, Feb. 2006.

[9] S. R. Saunders, Antennas and Propagation for Wireless Communication Systems. New York, NY, USA: Wiley, 2001.

[10] The Planar Inverted-F Antenna, accessed on Mar. 2016. [Online]. Available: http://www.antenna-theory.com/antennas/patches/pifa.php

[11] A.-H. Tsai, J.-H. Huang, L.-C. Wang, and R.-B. Hwang, ``High capacity femtocells with directional antennas," in Proc. IEEE WCNC Conf., Apr. 2010, pp. 1_6.

[12] M. Blanco, R. Kokku, K. Ramachandran, S. Rangarajan, and K. Sundaresan, ``On the effectiveness of switched beam antennas in indoor environments," in Proc. 9th Int. Conf. PAM, 2008, pp. 122_131.

[13] A.-H. Tsai, L.-C. Wang, R.-B. Hwang, and J.-H. Huang, ``High-capacity OFDMA femtocells by directional antennas and location awareness," IEEE Syst. J., vol. 6, no. 2, pp. 329_340, Jun. 2012.

[14] Y. Li, Z. Feng, D. Xu, Q. Zhang, and H. Tian, ``Automated optimal configuring of femtocell base stations' parameters in enterprise femtocell network," in Proc. IEEE Global Telecommun. Conf. (GLOBECOM), Dec. 2011, pp. 1_5.

[15] S. N. Diggavi, N. Al-Dhahir, A. Stamoulis, and A. R. Calderbank, ``Great expectations: The value of spatial diversity in wireless networks," Proc. IEEE, vol. 92, no. 2, pp. 219_270, Feb. 2004.

[16] Mailloux, R.J., et al, "Microstrip antenna technology", IEEE Trans. Antennas and Propagation, Vol. AP-29, January 1981, pp.2-24.

[17] James, R.J., et al, "Some recent developments in microstrip antenna design", IEEE Trans. Antennas and Propagation, Vol.AP-29, January 1981, pp.124-128.

[18] 6x9 Handbook / Antenna Engineering Handbook / Volakis / 147574-5 / Chapter 7

[19] Yu-Wei Fan, Hui-Huang Zhong, Zhi-Qiang Li, Heng Zhou, Wei-Hong Zhou, lun Zhu and Ling Luo "A SHORT DIPOLE ANTENNA" College of Optoelectric Science and Engineering, National University of Defense Technology, Changsha 410073, China

[20] NTT DOCOMO. W-CDMA/LTE Dual-Mode Ultra-Compact Base Station (Xi Femtocell), accessedon May 2016. https://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/rd/ technical_journal/bn/vol15_2/vol15_2_056en.pdf

[21] Airspan Successfully Demonstrates Its IP-CoMP Technology in a 3.5 GHz Band 42 With SoftBank Japan. [Online]. Available: http://www.airspan.com/2015/02/24/airspan-successfully-demonstratesits- ip-comp-technology-in-a-3-5-ghz-band-42/

[22] Apple AirPort Time Capsule, accessed on Jun. 2016. [Online]. Available: https://www.apple.com/airport-time-capsule/specs/

[23] Sumanpreet Kaur Sidhu , Jagtar Singh Sivia , " Comparison of Different Types of Microstrip Patch Antennas" International Journal of Computer Applications (0975 – 8887) International Conference on Advancements in Engineering and Technology (ICAET 2015) 12