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Broadband Multiband Phased Array Antennas for Cellular Communications

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***Abstract* – More and more frequency bands are used in cellular (mobile) communications, driving base station antennas to be broadband and multiband. Architecture, design principles and methods of novel dual-polarized multiband phased arrays (nesting, cloaking, choking) are discussed and illustrated with practical examples of these high-complexity antennas.**

***Index Terms* – Multiband phased array, base station antenna, cellular communication, passive intermodulation (PIM), phase shifter.**

1. Introduction

The era of multiband phased arrays (MPA) began in 1970s, when first MPAs for fighter jets were deployed [1], with X-band and L-band radiators incorporated in a multi-functional aperture. Wide 2D scan angle (usually +/-45°) and high quantity of radiators of both bands are typical for these first MPAs. In last 40 years, numerous MPA were developed for defense and commercial applications. The focus of current paper is advances and challenges in multiband phased array base station antennas (MPBSA) for cellular communication.

2. Main Features of MPBSA

As illustrated by Fig.1, one MPBSA can replace up to 12 single band antennas.

Typical modern MPBSA is combining in the same aperture dual-polarized radiators of two bands: Low Band (< 1GHz) and High Band (>1GHz). Recent MPBSA has LB = 694-960 MHz, and HB=1695-2690MHz, i.e., both LB and HB are broadband, covering 35% and 45% of bandwidth correspondently [2]. To increase communication system capacity, new portions of LB and HB are coming almost every year, and next generation of BSA (under design right now) should be covered 548-960 and 1427-2690 MHz, almost octave in each band. Some applications even required packaging of 3.4 – 3.8GHz radiators into the same aperture [3], but for the most current LTE applications one column of LB elements and two columns of HB elements is required, as proposed in [3].

Achieving tremendous bandwidth is not the only challenge for MPBSA. Another challenge (especially for LTE systems) is passive intermodulation (PIM), and each port of antenna need to have 3rd order PIM <-150 ~ -153dBc for 2x20w tones [2]. Very strict PIM requirement is preventing employment of electronic phase shifters; only electromechanical phase shifters (with motors) are currently used. Multi-arc phase shifters combined with power divider [4, 5] provide good impedance matching and true time-delay over octave band. Notched transmission line [5] allows make multi-arc phase shifter very compact, even for tremendous continues phase shift up to 0° - 2000°, which provides beam tilt range of 0 - 25° for 1.3m antenna in 1.4-2.7GHz band.

MPBSA can increase potential harmful PIM (PIM that falls in the receive band). For example, AWS1/3 combined with 700MHz band results in 3rd order PIM hits 700 band. PIM calculator [2] is a useful tool for PIM mitigation.

3. Design Methods and Principals of MPBSA

(1) Nesting

One of the main challenges for MPBSA is blockage of HB elements by LB elements, which are located nearby. There are several methods to make LB element low-observable for HB frequencies. One of them is nesting [6],

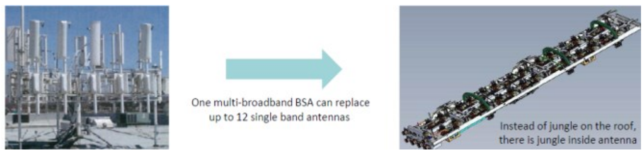

Fig.1. One MPBSA is replacing several single-band antennas.

when HB radiator placed inside LB, as shown in Fig.2. Dual-polarized HB crossed dipoles are located inside LB radiator (also dual polarized) which is low-profile microstrip annual ring. On the top of HB dipole, directors can be used to make HB pattern narrower.

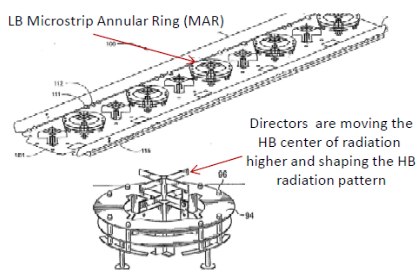

Fig.2. HB elements are nested inside LB element [6].

Fig. 3. Cloaked LB dipole with HB dipoles located under it.

(2) Cloaking

Dual-polarized reduction of LB dipole blockage by using mantle cloaks also can be performed [7]. Metal cylinders with special hole pattern and dielectric cover can be used for this. In Fig. 3, cloaked LB dipole with dielectric coverage is shown. The cloak usually does not affect LB radiation pattern, but can make LB impedance matching more difficult, i.e., there is trade-off between HB performance and LB return loss tuning.

(3) Filters, Chokes, Traps in LB Dipoles Arms

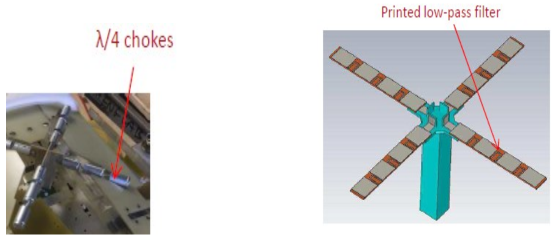

Fig. 4. Chokes and filters in the arms of LB dipole.

λ/4 chokes (λ is HB wavelength) can disturb HB currents excitations in the arms of LB dipole and make it low-visible for HB radiation (see Fig.4.). But λ/4 chokes are relatively narrowband, and more complicated filters (discrete or printed) can be used, as also shown in Fig. 4. Miniature surface mount bandpass filters can further improve low-visibility of LB dipole.

(4) Filtered MPBSA

As we mentioned above, filters can play significant role to reduce blockage effect. Also, cavity and printed filters can be integrated in modern MPBSA to divide LB and HB to sub-bands to perform independent beam tilt in each of sub-bands [2].

(5) Lensed MPBSA

By placing dielectric lens in front of MPBSA, further improvements of antenna performance can be achieved. In particular, multiband multi-beam operation can be done, and grating lobes can be improved [9]. Low cost artificial dielectrics allow dramatic reductions in antenna weight and improve polarization characteristics [9].

(6) Special Configuration of LB Element and Array

Blockage effect can be also reduced by proper selection of array configuration [8] and, in addition to this, by using of special LB element: tri-pole [10], as shown in Fig. 5.

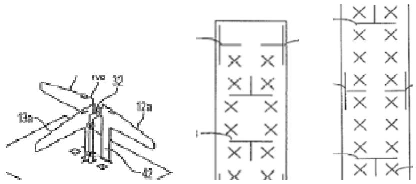

Fig. 5. Tri-pole and MPBSA with LB tri-poles

Tri-pole has only three arms, not four as regular dipole, and his arms are located between HB dipole, not directly on the top of them (compare to Fig.3).

(7) Tightly Coupled Arrays

For future development, tightly coupled arrays [11], 12] could provide further progress for MPBSA, but, so far, dual polarization is a challenge.

4. Conclusion

Despite of growing complexity, several million MPBSAs were produced worldwide in last couple years. More challenges are coming (wider bandwidth, more integration with electronics), but challenges are always inspired innovations.

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