Antennas for Dual-Band Networks

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1 Introduction

Mobile phone networks are living through times of unprecedented growth in the subscriber base and the number of services being offered. At the same time operators are encountering growing pressures from planners and environmental groups. At present the industry needs smaller and less conspicuous base stations with reduced unit cost, all achieved with no compromise in performance.

1.1 Adding a frequency band

The pressure on spectrum in the 900MHz band has led to the grant of licences for networks to operate in both the 900MHz and 1800MHz bands. In some countries where 1800MHz operators have faced difficulties in providing sufficient coverage in less-populated rural areas, some 900MHz spectrum has been made available to allow coverage to be extended at lower cost.

Wherever an operator is adding an additional band, the cost of implementation must be held to a minimum, and the planning problems must be effectively managed. The effectiveness of the existing network must not be compromised.

1.2 Polarisation diversity

The use of polarisation diversity has become increasingly established as a technique which, at least in urban areas (where capacity pressure is greatest) is comparable with space diversity. The compact physical form of polarisation diversity antennas - and their suitability for pole mounting with no complex head frame - has provided a timely solution to some of the industry's environmental problems.

Where it is necessary to add a second band at a base station using space diversity, a simple solution is to replace the existing antennas with a pair of dual-polar antennas, one for 900MHz and the other for 1800MHz.

The discussion below specifically relates to dual-band, dual-polar antennas, which are the dominant requirement for new dual-band base stations.

2 Possible design solutions

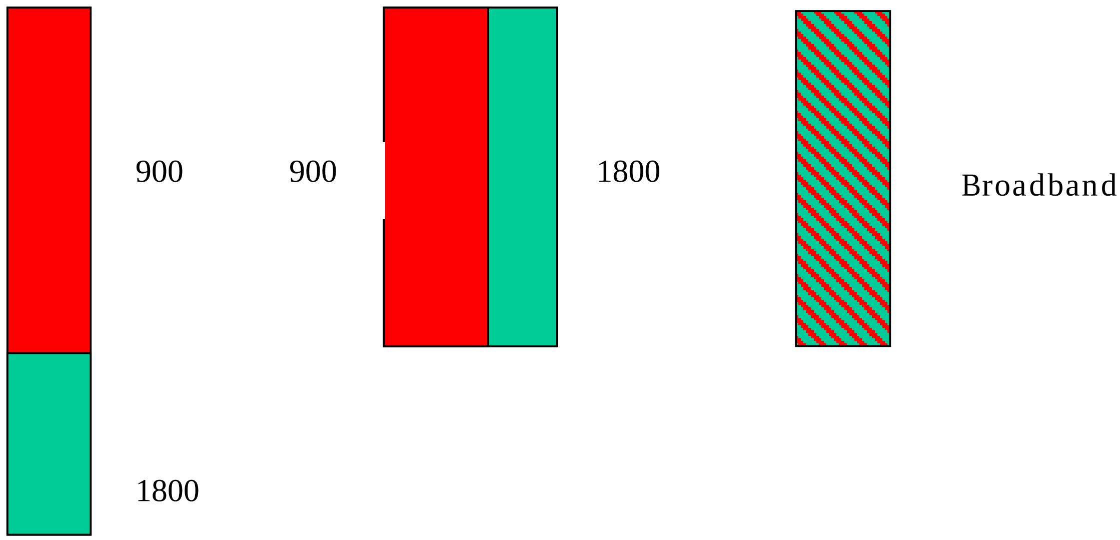

Figure 1: Some possible configurations for a dual-band, dual-polar antenna

Options for the configuration of a dual-band antenna, shown in Figure 1 include:

- 900MHz and 1800MHz antennas in line

  This results in a longer profile for a given antenna gain, but allows substantial independence of antenna performance on the two bands.

- 900MHz and 1800MHz antennas side-by-side

  This results in a wider antenna profile and is likely to result in azimuth pattern squint caused by the asymmetry of the two arrays.

- Broadband antenna array

  This is attractive in concept. Element design is feasible, but an octave band arrays will have compromise performance, especially in respect of elevation pattern shaping.

2.1 An interleaved array

An interleaved array offers a number of advantages over the configurations in Figure 1, while maintaining the almost complete independence of the two constituent arrays. Like the broadband array, it maintains the same profile as a 900MHz antenna having the same gain.

The interleaved array creates a number of design challenges, especially if the design incorporates dual-band elements. These include:

- Radiating element design
- Achievement of azimuth pattern equality between bands

- Achievement of isolation between polarizations and between bands

If dual-band elements are used, the antenna designer can exploit the octave frequency relationship. The technique minimises radiation pattern disturbance caused by the elements for the 'other' band, reduces coupling, and minimises the total complexity of the design. The use of interleaving permits an independent choice of the antenna gain, elevation beamwidth and electrical elevation tilt on the two operating frequency bands.

The achievement of a practical antenna presents a considerable challenge to the antenna designer, and the network user will be interested in the trade-offs which may be involved.

2.2 What are the trade-offs in using a dual-band antenna?

In comparing an interleaved dual-band, dual-polar antenna with two separate single-band antennas, we find the following:

- **Azimuth beamwidth**

  The use of the same physical structure may result in some difference in azimuth beamwidths between bands. With careful design this difference can be controlled, but especially on 1800MHz there is typically slightly more variation in azimuth beamwidth over the band.

  In general, where the operator is adding a new frequency band to an existing network, the most important consideration is to maintain the same performance in the existing band: some compromise may be acceptable on the newly-introduced band. This is especially true where the new band is to be introduced to increase capacity for existing network services. Where the objective of the operator is to overlay a new network carrying alternative services, the antenna requirement is different, as closely matched coverage may be more important.

- **Elevation beamwidth, shaping and electrical tilt**

  These parameters can be independently chosen and optimised, with no significant compromise compared with the single band antennas. The number of elements for each band can be chosen independently. As the arrays have entirely separate feed networks, their electrical tilts, null fill and upper sidelobe suppression can be separately chosen and optimised.

- **Gain**

  There is no significant loss of gain on either band. The ability to optimise the feed networks independently allows the array to function independently and no gain compromise is involved. This is particularly true of the 900 / 1800MHz band pairing, where no real compromise is required on element spacing (an 800 / 1900MHz pairing would require compromise).

  At the present time, network operators choose the relative gains of the 900MHz and 1800MHz arrays using two different criteria:

- The same gain and elevation beamwidth on 900MHz and 1800MHz – *ie* the 900MHz and 1800MHz arrays have the same number of elements, but the 1800MHz array is half the length of the 900MHz array.
- Both arrays are chosen to be the same gain / length as the typical single band antennas, usually 6 - 8 wavelengths at 900MHz and 12 wavelengths at 1800MHz. In this configuration the 1800MHz antenna will have a higher gain than the 900MHz section, partially offsetting the difference in propagation loss, but the different elevation beamwidths may result in some other coverage differences.

- **Isolation**

Inter-band isolation is usually adequate, but the achievement of high cross-polar (cross-port) isolation is more difficult than for a single-band antenna.

An isolation of 30dB is required between the ports of the BTSs to avoid excessive levels of IMP generation when a dual-polar antenna is fed with transmit signals at both ports. This isolation is not easy to achieve in a single-band antenna and the increased complexity of a dual-band antenna makes it more difficult. Some reduction may be acceptable at the BTS receive frequency where other filters in the system can easily cope with reduced antenna isolation.

Inter-band isolation is required between the 900MHz and 1800MHz sections of the antenna to allow them to operate correctly, because if 1800MHz currents are permitted to flow on 900MHz elements the radiation patterns at 1800MHz will be corrupted. Where antennas are fitted with a diplexer to allow both bands to share a single feed cable, there is no ability to measure or specify an inter-band isolation for the antenna and the designer must ensure sufficient isolation to obtain clean radiation patterns and low input VSWR.

3 Diplexers

Most dual-band antennas in current production are fitted with an internal diplexer as shown in Figure 2.

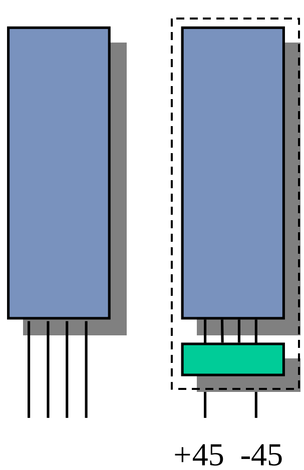

Figure 2: The use of an integral diplexer allows the dual-band, dual-polar antenna to be fed with only two cables. This avoids the requirement to fit existing cables where an existing single-band system is being upgraded.

The use of an integral diplexer may not be appropriate when mast-head amplifiers are to be fitted only for the 1800MHz band.

4 The challenge of rising complexity

A dual band, dual-polar antenna typically comprises 8 + 8 + 12 + 12 (= 40) radiating elements. Compared with the single-band plane-polar antennas of a couple of years ago, this increased complexity raises important questions of reliability and stability of design, both in production and in network operation..

4.1 Choice of feed network technology

Coaxial cables have traditionally been used in base station antennas, but the growing complexity challenges reliability and consistency of product.

Microstrip feed networks provide intrinsic high reliability and can easily be adapted to more complex networks. They are easy to reproduce in production and provide the designer with a high degree of flexibility when meeting requirements for optimised elevation patterns. They yield good economies when manufactured in large numbers but have a relatively high development cost.

4.2 The challenge of variety

The move towards dual-band networks has created many challenges for the antenna designer. The current demand for large varieties of product slows development; it increases the costs of both development and production, and extends delivery times. The use of microstrip feed technology improves product reliability, but is not economic when large numbers of product variety are required by the market.

5 Conclusion

Dual-band antennas have been successfully designed and manufactured to meet the requirements of network operators. They have similar characteristics to the previous generation of single-band antennas, allowing existing networks to integrate them without major operational disturbance or large-scale re-optimisation of existing networks.

The advent of 3G will provide further challenges of cost, environment and change and it is important for the industry that the experience of conversion to dual-band operation is used to make the coming larger transition as easy as possible.

Footnote:

Patents The design of the interleaved dual-band array is the subject of current international patent applications by CSA Limited.