Antenna Design in the Band 1 - 2GHz

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Introduction

The frequency band between 1 and 2GHz is finding increasing application for satellite and land mobile services. In antenna technology it lies in a crossover region in which techniques which are used at frequencies in the VHF and UHF bands merge with microwave designs. This paper takes a broad look at the antenna types which are suitable for the band, with particular reference to the practical problems of their mechanical construction and relative cost.

The most severe mechanical problems arise from the need to maintain close manufacturing tolerances, especially in antenna terminal regions. The effect of the environment on antenna performance is also very significant, as a single drop of water in the wrong place can entirely disable an antenna. These problems will constrain the techniques which we can adopt to solve most of the problems we will examine.

Low-directivity Antennas

Until the last few years there were few applications for low-directivity antennas in the band, except as feed units for reflector antennas. The advent of simple low-capacity satellite services has created a need for antennas with almost hemispherical coverage and substantial bandwidths.

According to the exact beamwidth needed, the following types of design are available, and the choice between them lies as much in the economics of construction as in their electrical performance:

1. Helices - single, bifilar and quadrifilar
2. Log-periodic planar and conical spirals
3. Log-periodic Dipole Arrays (LPDAs)
4. Lindenblad dipole arrays
5. Patch radiators
6. Simple cavities
7. Slots and slot/reflector combinations

This wide choice, and the varieties of each which find application in current commercially successful antennas, indicates the unusual scope for the antenna designer in this frequency band.

Simple helices can be constructed using the same techniques as are used at lower frequencies - supporting the radiating element from a central supporting boom. This type of antenna becomes too small for convenience at 2GHz, and needs a protective radome to keep the weather off.

Quadrifilar helices have become popular, but these antennas are fairly complex - especially as they need two baluns and a 90-degree phase shift circuit of some type. Production volumes are seldom large enough to adopt the kind of mechanical design which could lead to really low costs, and to obtain optimum performance a large number of mechanical components must be made and assembled with great accuracy.

Planar spirals are easily and cheaply produced by printed circuit methods and need only a simple balun to feed them. They are common for ESM applications, but are usually not very efficient and have only modest cross-polar performance.

Conical spirals produce useful radiation patterns over wide operating bandwidths; unfortunately their three-dimensional form is difficult to print, and rolling a two-dimensional printed circuit is not an attractive method for production. The ease with which their beamwidth can be controlled makes them very useful as feeds for reflectors.

LPDAs or other forms of log-periodic - trapezoidal tooth forms are fairly common - can be constructed using printed circuit methods or by electro-chemical etching from self-supporting thin metal sheet. The antenna is usually supported in a plastic radome to protect it from the weather. There are some beautifully-executed examples of these antennas in commercial production, the dual or circularly polarized crossed forms are real works of art!

Lindenblad arrays provide circularly polarized omnidirectional coverage from an antenna which is mounted around the supporting member, but again the complexity of the device - with four dipoles and four baluns - makes it very expensive to produce.

Patch radiators have become very common during the past few years and have the attractive features of being easy to reproduce accurately in large numbers. They suffer the disadvantage of comparatively narrow bandwidth, even if stacked or multiple patches are used. While the bandwidth of a single element may be sufficient, problems arise when designing multiple-element arrays, especially if closely controlled radiation patterns are needed over an extended bandwidth. Some ingenious impedance-compensation methods have emerged, but their high Q-factor makes them rather lossy (resulting in increased noise temperature). The cost of suitable close-tolerance low-loss dielectric materials remains fairly high, inhibiting their use in low-cost applications. It is interesting to see that in the 900MHz band several designs have recently appeared in which the patch element is self-supporting with no dielectric underneath; this loses the opportunity for using PC construction to obtain close tolerances.

Simple cavities are used as feeds for reflectors, and as simple robust low directivity antennas. They are simple to construct and few components are required to make a wide-band quarter-wave probe with which to excite them.

Slot antennas and slot/reflector pairs are also in use as feed elements for reflectors.

Many of the types of antenna which have been mentioned have similar electrical characteristics, and the choice between them will be made on the basis of the mechanical method of construction which is available to the designer and which is appropriate to the quantity of antennas which are needed.

Medium-directivity antennas

The choice here lies between broadside or planar arrays formed from the low-directivity elements listed above and various forms of endfire antennas. Arrays are limited by the accuracy and losses of the feed network and associated power dividing components, which may be built in coaxial line, fabricated strip or tri-plate, or printed-circuit lines; often these techniques are mixed, with the feedlines and splitters using different methods of construction, generally because of the high cost of low-loss dielectrics for stripline.

Endfire antennas comprise a launching device which illuminates some form of slow-wave structure. Forms which are frequently encountered include:

1. Yagi antennas
2. Axial-mode helices
3. Short backfire antennas
3. Zig-zag antennas
5. Dielectric rod antennas

Yagi antennas are popular at lower frequencies, but in this band the main problem is to construct a dipole element and balun with the close mechanical tolerances which are needed. An elegant solution which overcomes this problem is provided by the cavity-fed Yagi in which the dipole and reflector elements are replaced by a probe-excited cavity which launches a wave along the slow-wave structure formed by the director array.

Axial-mode helices can be built by supporting the radiating element on short rods, or by winding it round a rod or tube. The gain, radiation patterns and bandwidth of helices can be controlled within wide limits by techniques such as tapering the diameter of the helix and changing the pitch angle of the element; bandwidths in excess of an octave can be obtained by these methods.

Back-fire antennas have been around for many years, but seem to have been slow to find practical application. Because of their mechanical form and comparative ease of manufacture, they are increasingly seen at L-band providing gains of 10-14dBi.

Zig-zag antennas can readily be made by printed-circuit methods, or by a bent wire. They form a useful low-cost antenna of modest bandwidth

Dielectric antennas were much investigated some years ago, but are not often seen in use. Some time ago the author's group investigated an antenna using an artificial dielectric comprising randomly dispersed conducting obstacles in a foam matrix; it worked, but it proved much simpler and cheaper to substitute an alternative slow-wave structure in the form of an array of Yagi directors. The Cigar antenna is still to be seen in this frequency band, and may be seen as an alternative form of slow-wave structure, analogous to an artificial dielectric, but it is probably more complex and expensive to construct than a long helix.

High Gain Antennas

Unidirectional Antennas

Large multi-element arrays become expensive to build, whether they use fabricated mechanics or stripline methods, and for power gains exceeding about 20dBi, the most usual form of antenna is the front- or offset-fed reflector, using one of the low-directivity antennas described above as the feed. Large arrays of patches or dipoles are used when beam-steering or other functions are needed, but here the cost of the basic antenna is no longer the design driver and the extra cost must be tolerated. The use of rodded or perforated reflectors is well established in this frequency band
and the limitations of electrical performance which this method brings are well understood.

Omnidirectional Antennas

An increasing number of applications are emerging for omnidirectional antennas operating in the 1-2GHz band. The methods currently in use employ series fed radiating elements, or collinearly-mounted fat dipoles fed in parallel using a system of branched cables.

The first of these methods is an extension of the techniques which have been developed for mobile radio base stations in the 900MHz frequency band; the antenna comprises an assembly of identical radiating elements which are threaded onto a central feed line. The method is intrinsically fairly limited in bandwidth, as a progressive phase error appears across the aperture of the array as the frequency moves away from the design frequency. This effect can be mitigated by centre-feeding longer arrays, but the problem of poor control of element excitation makes it very difficult to control the elevation pattern of the antenna. As the impedance characteristic of these arrays is also unfriendly over a wide bandwidth, considerable ingenuity is needed to devise suitable matching structures at the feed point.

Fat-dipole arrays can accommodate a branched feed system inside the central support from which the dipoles are mounted. The arrangement allows good control of elevation patterns, but the dimensions of the feed cables are restricted by the size of the central tube; as the tube becomes larger it becomes more difficult to obtain circular azimuth patterns, as the phase of excitation varies around each element. The cost and complexity of the feed cables and their associated splitters also limits the application of this type of design.

Antenna designers are currently addressing the design problem posed by omnidirectional antennas in this band and it will be interesting to see how they improve on current designs to meet the growing needs of their customers. Once again the main problems are presented by the constraints of mechanical design and economics of the available methods of production.

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