Antenna Modelling Made Easier part -1 Background

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PART-1 of a two part article **G8ODE RSARS 1691**

Introduction.

When radio hams are asked to describe a simple HF antenna, most will begin to describe a "dipole", and probably be thinking about a resonant half-wave antenna, rather than a non-resonant dipole. Many radio hams have a limited knowledge of antennas and antenna theory. In the majority of cases the knowledge is restricted to a basic facts about a few HF antennas, such as the G5RV, Carolina Windom, inverted "L", W3DZZ, but know very little about the actual performance of the antennas erected at their home location.

Most of us have, at some time, glanced through antenna text books to find far field plots and formulae to make an antenna and then used 1/4λ = 234 / F(MHz) feet or 75/ F(MHz) metres. The books are likely to mention something about the antennas' other properties at certain heights and orientation. However, there will be scant information concerning the dipole, or any other antenna, that may have been erected in the back yard of a small terrace house with properties that differ from the text book model, notably the height, orientation, feeder length and possibly close to metallic structures.

Even the simple formula for the quarter wave element hides some daunting complex science and mathematics that most of us are unaware. In fact, if a multi-element antenna is considered, matters get even more complicated because of interactions between the elements. The science behind antenna modelling goes back a long way and involved many great people, so it's perhaps a good idea to remind ourselves of some of them.

The Time–Line

Perhaps a good starting point is Andre-Marie Ampere (1775-1836), after whom the unit of current is named. Others include Garl Freidrich Gauss (1777-1855) for his work on magnetism, Georg Simon Ohm (1789-1854), whose name is given to the unit of resistance and Michael Faraday (1791-1867), who studied the magnetic field

around a conductor carrying a DC electric current. While conducting these studies, Faraday established the basis for the electromagnetic field concept in physics, subsequently enlarged upon by James Clerk Maxwell (1831-1879), whose most prominent achievement was formulating classical electromagnetic theory.

Five other other great "Maxwellian" scientists increased our understanding of the science behind the antenna. These men, George Francis FitzGerald (1851-1901), Oliver Heaviside (1850-1925), Oliver Joseph Lodge (1851-1940), Heinrich Rudolph Hertz (1857-1894) and John Henry Poynting (1851-1914), developed the mathematics needed to enable the science of radio antennas to progress.

Great entrepreneurs like Edison, Dolbear, Hertz, Tesla and Marconi all recognised the potential of radio communications and gave several radiation demonstrations between 1875-87. Did these great men realise that what they were starting would change our world so much? Changes such as the development of radio broadcasting, television, radar, radio astronomy, satellite communications, GSM mobiles and WiFi links to computers to mention just a few things.

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At the turn of the last century others were concentrating on the way to launch radio waves. In 1897 Professor Adolf Slaby and Count von Arco erected the first German antenna system for wireless communication and OJ Lodge developed the bi-conical dipole, loading coil, tuneable LC matching network and counterpoises.

Alessandro Artom developed phased array technology between 1889 and 1906, and Marconi created the fan dipole and polar plots between 1895 and 1901. In 1907 Bellini & Toss produced the goniometer and steerable array, which led to more sophisticated direction finding techniques. In the same year Zenneck wrote about ground losses and ground waves.

Much later, in 1926, Uda and Yagi created the antenna that is now commonly as the Yagi, which proved itself during WWII when airborne radar was developed and deployed by the RAF on Bristol Beaufighters and other aircraft. When some American documents fell into Japanese hands they failed to realise that "Yagi" was not a code word for the antenna but the name of their own scientist.

All these pioneers inspired future scientists to further develop the science to be able to study the behaviour of antennas in a variety of configurations and environments. This required an in depth understanding of how radio frequency currents behave in a linear conductor. Fortunately Maxwell and his peers laid the foundation stones for further development in this area but the mathematics was becoming very complicated. This was to be the next big challenge.

A new mathematical approach for the study of antennas was required. The Method of Moments was conceived by I G Bubnov (1872-1919) and further developed by B G Galerkin (1871-1945) as the "*method* of statistical *moments* for nonlinear mechanical systems". In 1959, the paper "Method of Moments" was published by AV Kantorovich and GP Akilov and, in 1967, RF Harrington further simplified the analysis by introducing the "Matrix method for Fields Problems". Soon after this a computer program was written in the FORTRAN programming language to run on main-frame computers of the day. This, in turn, led to the development of a US Government Laboratories program called Numerical Electromagnetics Code (NEC) for solving general electromagnetic radiation problems.

The Software Programs

NEC is described as "a moment method surface integral technique modelling a scatterer or antenna by wires".

N.B. "scatterer" refers to the way conducting objects or surfaces reflect radio waves e.g. the ground under the antenna or even the reflectors & directors on a Yagi antenna

The majority of antenna analysis programs used today are derived from the same NEC program, which uses a "Method of Moments" algorithm. The mathematics involved would discourage most radio amateurs, but the basic principle is simple.

For modeling purposes, an antenna is broken down into a number of straight-line wire "segments" and the field resulting from the RF current in each segment is evaluated by itself and also with respect to other mutually coupled segments. Finally, the field from each contributing segment's vectors are summed - to determine the total field and to generate a model for any elevation or azimuth angle desired.

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It sounds as if this has simplified the study of antennas for the radio amateur , yes, it has, but not completely! Over the years simplified versions of the NEC software have been improved to remove some of the limitations imposed by less powerful domestic computers.

Further Software Improvements.

NEC-1 (1979) - improved currents accuracy , multiple wire junctions; thick wires.

NEC-2 (1981) – Sommerfield-Norton ground interaction for wire structures above lossy ground.

NEC-3 (1985) – handling of buried wires

NEC-4 (1992) – further improved accuracy for stepped-radius wires, smaller segments

Latterly,

EZNEC is specifically designed to be friendly and easy to use while taking full advantage of the powerful and versatile NEC-2 calculating engine. EZNEC is completely menu-driven.

WIPL-D – (1994) is a New MoM program that represents a generalisation of the MSDOS MoM program for conducting bodies.

FEKO (c2000)- In order to solve electrically larger structures the MoM has been hybridized with high frequency techniques such as Physical Optics and the Uniform Theory of Diffraction.

Mini-NEC – Is a cut down version of the FORTRAN NEC designed to run on desktop PCs and enabling more radio amateurs to use the program.

Definition of The Method of Moments

Method of Moment s ; A method for solving integro-differential equations such as Pocklington's equations (1897) at a given frequency or Hallen's (1938) equation.

- **Pocklington's equations (1897)**

$$\left[\frac{d^2}{dz^2} + k^2\right] \int_{-h}^{+h} I(x)\, g(z-x)\, dx = -\frac{4\pi jk}{\zeta} E_z^i(r=a,z) ,$$

- **Hallen's equation (1938)**

$$\int_{-l/2}^{l/2} I_z(z') \frac{e^{-jkR}}{4\pi R} dz' = -j\sqrt{\frac{\varepsilon}{\mu}}\left[B_1 \cos(kz) + C_1 \sin(k|z|)\right]$$

Fortunately, generous radio amateurs and professionals have given their time freely to write menu driven software that anyone can use on the Windows desktop PC or laptop, we don't really need to worry about what the equations mean or how to solve them.

That's the easy part, well no, perhaps not completely, but this will be explained in Part 2 of this article.

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