Optimization of Gain and Bandwidth for Very High Frequency Patch Antenna

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***Abstract*— The aim of this paper is to establish a method to improve the Gain and Bandwidth throughout the VHF range. The effect of different dielectric materials, shape for the patch, various slotting methods are reviewed and the design giving the best results is established.**

***Keywords*— Patch antenna; gain; bandwidth; dielectric loading; slotting; miniaturization**

I. INTRODUCTION

Microstrip or patch antennas are becoming increasingly useful because they are easy to fabricate and can be printed onto a circuit board directly. Microstrip antennas are becoming very widely used in the mobile phone market. Patch antennas are low cost, have a small size and are easy to fabricate. The gain of patch antennas is around 5-7 dB. Also the bandwidth of the patch antenna is very small. Rectangular patch antennas are narrow band; the bandwidths of rectangular microstrip antennas are typically 3%. With the rapid growth of wireless communications and increasing demand for high data-rates, many upcoming antennas must be ultra-wideband (UWB). A single antenna is a very attractive solution to handling the large bandwidth requirements. Antennas designed for VHF communications are usually big and protruding due to long wavelengths; e.g., 1λ =10 meters at 30 MHz. Most applications located in VHF band experience difficulties in using such a big antenna because of its large size and weight. When those antennas are designed to situate on terrestrial and airborne platforms, those difficulties become more severe.

II. THEORY

Bandwidth, gain and efficiency of a Micro-strip antenna depends upon size of the patch, its shape, thicknesses of substrate, dielectric constant of substrate, type of feed used and its location, etc. As stated in [4], impedance bandwidth is inversely proportional to the quality factor. And quality factor Q can be changed by changing the permittivity and height of the substrate. Quality factor is directly proportional to permittivity. Substrate acts as a capacitor hence as permittivity increases, capacitance also increases thereby increasing the stored charge and Q. Due to this, the bandwidth decreases. Likewise if the height of the substrate increases, capacitance decreases owing to the fact that capacitance is inversely proportional to distance between the plates. This decreases the Quality factor and therefore increases the impedance bandwidth. For good antenna performance, a thick dielectric substrate having a low dielectric constant is required for higher bandwidth, good efficiency and better radiation, leading to a larger antenna size.

III. METHODS TO MINIATURIZE THE ANTENNA

Electrically small antennas can be made by lowering the resonance frequency, arranging for uniform current distributions or by making full utilization of the volume or surface circumscribing the longest dimension of the antenna. These methods are elaborated on as follows as stated in [6]:

A. Lowering the resonance frequency

When an antenna having typically small dimensions thereby greater frequency of operation is made to operate at lower frequency, such an antenna is called an electrically small antenna. This can be achieved most effectively by introducing a slow wave structure in the antenna. A slow wave structure is that structure which reduces the velocity of an electromagnetic wave travelling through it. These structures are periodic in nature or can be achieved by use of material loading or modification of antenna geometry. Each of these methods is as follows:

- Shapes such as helical shapes, meandering paths and zigzag shapes are examples of periodic shapes. These shapes elongate the length the current has to travel. Also certain shapes have inherently low Quality factor Q and higher bandwidth like annular rings, helix, circular/ rectangular rings etc.
- Slow wave structures can be realized by modifying the shape such that current flow path is lengthened and phase velocity of the electromagnetic wave decreases as compared to the speed of the light. This can be done by introducing various slots in the patch shape.
- Loading of the antenna structure with dielectric, magnetic and metamaterials with some finite value of permittivity and permeability is another way to produce a slow wave structure thereby reducing the dimensions of the antenna for lower frequencies.

B. Arranging for uniform current distribution

In order to achieve maximum gain, this method is adopted wherein the current distribution on the surface of the patch has to be uniform. However this is very difficult to achieve as typically the current distribution is minimum at the ends and maximum at the center as in the dipole. In order to achieve uniform distribution, a capacitance termination is used. Also gain can be increased by proper impedance matching between the antenna and the characteristic gain of the system as stated in [1].

C. Complete utilization of volume or surface circumscribed by longest dimension in the antenna

This method suggests the use of the entire volume projected by the longest dimension. However it is not realizable. But this concept is followed by filling the space or volume efficiently. A multi-arm helical elongated to occupy the volume of a sphere is an example of this method, as shown in Fig. 1.

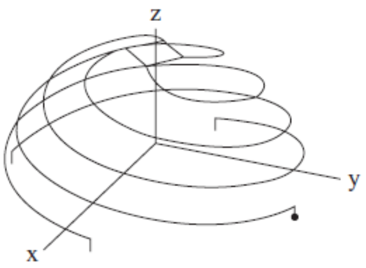

Fig.1- 4 arm helical antenna

IV. METHODOLOGY

Making use of the combination of above mentioned methods, an electrically small antenna for the Very High Frequency range (30- 300 MHz) can be realized as follows:

A. Type of Antenna

The grounded loop antenna inherently possesses a low radiation resistance. It is electrically small in size and light weight and also it is easy to fabricate. As stated in [7], the only deficiency in a small loop antenna is narrow bandwidth. The efficiency of an antenna is a function of radiation resistance by the sum of the radiation plus loss resistance. The radiation resistance in a grounded loop is much less than 1 Ω, so it is necessary to minimize the loss resistance, which is largely the skin effect loss of the conductor. However, if the loss is too low, the quality factor Q will be excessive and the bandwidth will be too narrow for practical use. The bandwidth can be improved by the use of some of the methods discussed above.

B. Dielectric for loading

As stated in [1], for the widest bandwidth, a high permeability constant material should be adopted. Ferrite loading is adopted to improve the gain. It is necessary that the ferrite material should have a low loss tangent for improved gain. For best performance, it is necessary for the dielectric material to have lower permittivity and thin dielectric height. Lower permittivity ensures higher bandwidth and greater efficiency; thinner dielectric gives reduction in antenna size. Various materials like RT Duroid, Rogers, 61-material, SO-20 etc are available to choose from.

C. Feeding method

There are a number of feeding methods like aperture coupled feeding, coaxial feeding, microstrip feedline etc. Out of all these methods for feeding the patch, coaxial or probe feeding technique is used. On the surface of the patch, impedance varies greatly from point to point. This is due to non-uniform distribution of current. The main reason for adopting probe feeding is that it can be placed anywhere on the antenna surface in order to provide proper matching with the system impedance (usually of 50 ohms). For impedance matching in a grounded loop antenna, the feed is provided at a point on the extreme edge along its width like shown in the Fig. 2

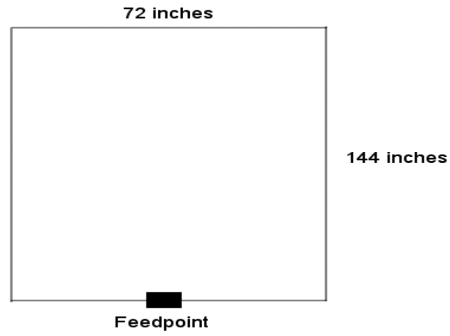

Fig 2- Grounded loop antenna feeding point

D. Use of slotting for bandwidth improvement

This is a method of lengthening the path of current flow. A slot of certain dimensions is etched on the patch structure. Various shapes of slots can be introduced like the straight slots, U-slots, Γ-slots. The antenna parameters vary greatly with the slot dimensions. Researchers have established that such slotting of the patch antenna shows significant improvement of bandwidth in an otherwise compact sized antenna having low bandwidth.

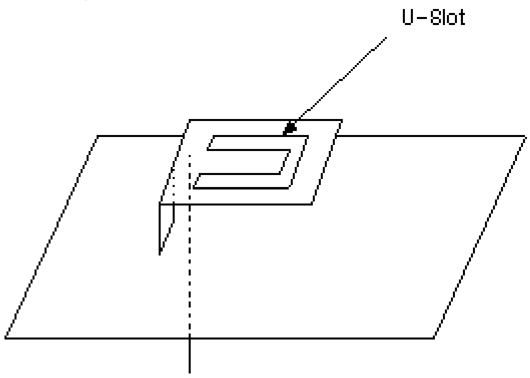

Fig 3- A U-slotted Grounded loop antenna

E. Software for Simulation

The software being used for simulation of the proposed antenna is Ansoft HFSS. HFSS stands for High Frequency Structural Simulator. HFSS is commercial finite element method solver for electromagnetic structures from Ansys Corp. It is based on the Method of Moments (MoM). It can simulate 3D antenna structures and their radiation patters can be observed. Also it can calculate VSRW, Return loss, Gain, Reflectivity coefficient etc.

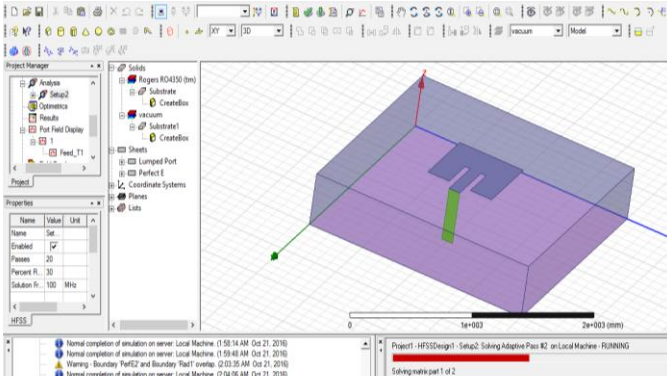

Fig. 4- HFSS interface

CONCLUSION

Due to the compactness and wideband property of the proposed antenna, it can be used in numerous applications. This antenna is designed with an aim to show improved performance in terms of gain, bandwidth, efficiency and compactness as compared to other patch antennas working in the same frequency range. This proposed antenna is designed with a combination of methods for performance improvement like the use of loaded dielectric and slotting. However further improvement of performance cannot be denied due to the great variety of methods available to improve the same.

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