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Triple Band PIFA Antenna Using Knowledge Based Neural Networks

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ABSTRACT

In this project, a compact triple band planar inverted-F antenna (PIFA) has been proposed. Triple band is achieved by inserting slots on the top radiating patch. The dimension of the patch is 12 x 15 mm2 and finite ground plane size is 44x 40mm2 which can easily be integrated inside the mobile phone. Further, a knowledge based neural network (KBNN) is used for designing of triple band PIFA. By using this method, accuracy is found to be really beneficial with the least amount of training data. This method requires less time and scales down the complexities of the design processes. The solutions obtained by this approach are compared with the CST simulation results. The results of the KBNN method are in good accord with the simulated values.

Keywords: Planar Inverted-F Antenna (PIFA), Knowledge Based Neural Network (KBNN), MATLAB and ANN Model.

1. INTRODUCTION

As mobile communication grows rapidly, the demand of wireless terminal operating at more than one band is increasing. At the same time, miniaturization of the communication equipments demands slim and compact mobile phone. Therefore compact multi band internal antenna for wireless communication is an explosive issue. Planar Inverted F Antenna (PIFA) has appeared as one of the most pledge candidate in the category of low profile antennas and is widely used for wireless communication. PIFA has a desirable multiband feature with higher efficiency, low profile, and lightweight. Because of these advantages, PIFA have become attractive candidates m multiband wireless communications.

Earlier conventional analytical and numerical techniques were used to design and analyze the performance of antennas. However, these conventional techniques require high computational efforts which make them complicated and time consuming. Simulation methods duplicate the same process even if a small change is done in the geometry, which also require lots of patience and time.

In the last decade, artificial neural networks (ANN), fuzzy, etc have been explored by researchers for modeling of antennas to bypass the lengthy full wave EM analysis and to avoid intensive use of CPU for simulations [3]. Thus neural networks are much important as fast and flexible tools for antenna modeling. Previous studies concerned with antenna modeling have mostly focused on microstrip patch antennas using neural networks, neural network combined with fuzzy.

Dual resonant frequency modeling considered recently for a slotted patch antenna with five design variables using knowledge based neural network and for PIFA with three design variables using ANFIS . But a large number of training data sets are required to train an ANN model to get sufficiently small prediction error. Whereas Knowledge based neural network (KBNN) reduces the number of training data required to train a neural network model. This happens because of reduction in the input- output mapping complexities of the network [II]. Prior knowledge to the network can be provided in the form of trained NN models, empirical models or analytical equations [II]. So KBNN modeling has been considered for this present work.

In this project, an effort has been made to design a compact triple band PIF A and KBNN is demonstrated for the first time to be a highly accurate and efficient technique for modeling the resonant frequencies of triple-band PIFA with design variables up to seven, which exceeds the number of design variables handled. Here, prior knowledge in the form of trained radial basis function network (RBFN) in addition with back propagation network (BPN) has been used.

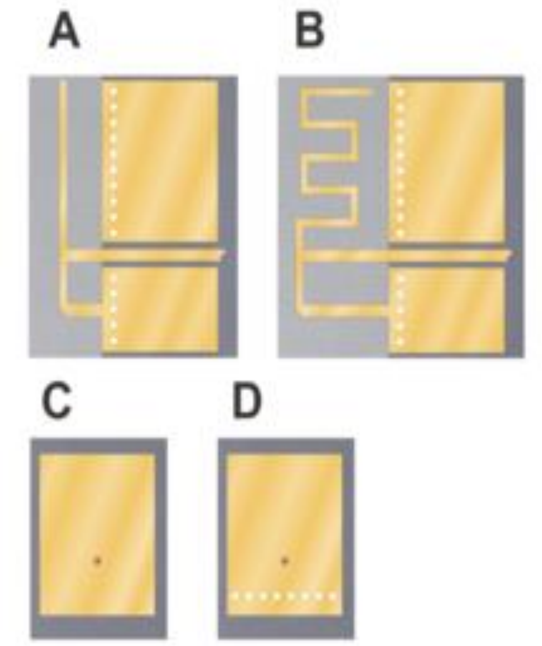
2. ANTENNA DESIGN

An antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz.

They are used as feed antennas (called feed horns) for larger antenna structures such as parabolic antennas, as standard calibration antennas to measure the gain of other antennas, and as directive antennas for such devices as radar guns, automatic door openers, and microwave radiometers. Their advantages are moderate directivity, low standing wave ratio (SWR), broad bandwidth, and simple construction and adjustment. One of the first horn antennas was constructed in 1897 by Indian radio researcher Jagadish Chandra Bose in his pioneering experiments with microwaves.

In the 1930s the first experimental research (Southworth and Barrow, 1936 and theoretical analysis (Barrow and Chu, 1939 of horns as antennas was done. The development of radar in World War 2 stimulated horn research to design feed horns for radar antennas. The corrugated horn invented by Kay in

1962 has become widely used as a feed horn for microwave antennas.



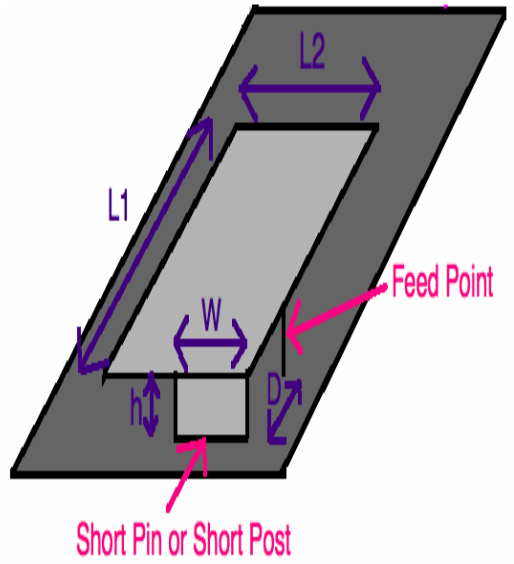
A: printed inverted-F antenna, B: meandered printed inverted-F antenna: C: patch antenna: D: Planar inverted-F antenna (PIFA)

▢ Board without ground plane
■ Board with ground plane
▣ Antenna feed pin
▣ Ground pin

An advantage of horn antennas is that since they have no resonant elements, they can operate over a wide range of frequencies, a wide bandwidth. The usable bandwidth of horn antennas is typically of the order of 10:1, and can be up to 20:1 (for example allowing it to operate from 1 GHz to 20 GHz). The input impedance is slowly varying over this wide frequency range, allowing low voltage standing wave ratio (VSWR) over the bandwidth. The gain of horn antennas ranges up to 25 dBi, with 10 - 20 dBi being typical.

A horn antenna is used to transmit radio waves from a (a metal pipe used to carry radio waves) out into space, or collect radio waves into a waveguide for reception. It typically consists of a short length of rectangular or cylindrical metal tube (the waveguide), closed at one end, flaring into an open-ended conical or pyramidal shaped horn on the other end. The radio waves are usually introduced into the waveguide by a coaxial cable attached to the side, with the central conductor projecting into the waveguide to form a quarter-wave monopole antenna.

The waves then radiate out the horn end in a narrow beam. In some equipment the radio waves are conducted between the transmitter or receiver and the antenna by a waveguide; in this case the horn is attached to the end of the waveguide. In outdoor horns, such as the feed horns of satellite dishes, the open mouth of the horn is often covered by a plastic sheet transparent to radio waves, to exclude moisture.



The Planar Inverted-F Antenna (PIFA), with a shorting Plane

In above Figure, we have a PIFA of length L1, of width L2. The shorting pin (or shorting post) is of width W, and begins at one edge of the PIFA as shown in Figure 5. The feed point is along the same edge as shown. The feed is a distance D from the shorting pin. The PIFA is at a height h from the ground plane. The PIFA sits on top of a dielectric with permittivity ε_r as with the patch antenna. The impedance of the PIFA can be controlled via the distance of the feed to the short pin (D). The closer the feed is to the shorting pin, the impedance will decrease; the impedance can be increased by moving it farther from the short edge. The PIFA can have its impedance tuned with this parameter.

$$if\ \ W = L2 \ \Rightarrow\ L1 = \frac{\lambda}{4}$$

$$if\ \ W = 0 \ \Rightarrow\ L1 + L2 = \frac{\lambda}{4}$$

Why does the resonant length of the PIFA depend on the shorting pin length W? Intuitively, think about how a quarter-wavelength patch antenna radiates. It needs a quarter-wavelength of space between the edge and the shorting area. If W=L2, then the distance from one edge to the short is simply L1, which gives us Equation.

What about when W=0? Since it is the fringing fields along the edge that give rise to radiation in microstrip antennas, we see that the length from the open-circuited radiating edge (the far edge in Figure 5) to the shorting pin is on average equal to L1+L2. You can convince yourself of this by measuring the distance from any point on the far edge of the PIFA to the shorting pin. The clockwise and counter-clockwise paths always add up to 2*(L1+L2), so on average, resonance will occur when the path length (L1+L2) for a single path is a quarter-wavelength. In general, we can approximate the resonant length of a PIFA as a function of it's parameters as:

$$L1+L2-W=\frac{\lambda}{4}$$

$$0.1+0.05-0.02=\frac{c}{4f\sqrt{\varepsilon_r}}$$

$$0.13=\frac{3\cdot10^8}{4f\sqrt{4}}\Rightarrow f=\frac{3\cdot10^8}{4\sqrt{4}(0.13)}=288.5\ MHz$$

To make things concrete, suppose L1=0.1 meters (10cm), L2=0.05 meters (5 cm), W=0.02 meters (2cm), and that ε_r =4. Then what is the resonant frequency? The solution can be found in

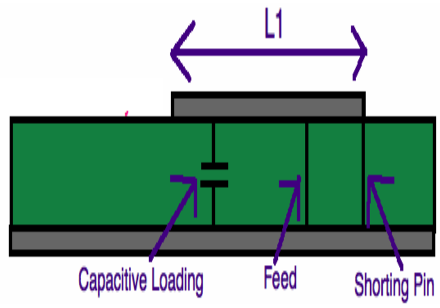
In note that we used one of the fundamental antenna equations, relating wavelength, speed of light and permittivity:

$$c=\lambda f$$

$$f=\frac{c_0}{\lambda\sqrt{\varepsilon_r}}=\frac{3\cdot10^8}{\lambda\sqrt{\varepsilon_r}}$$

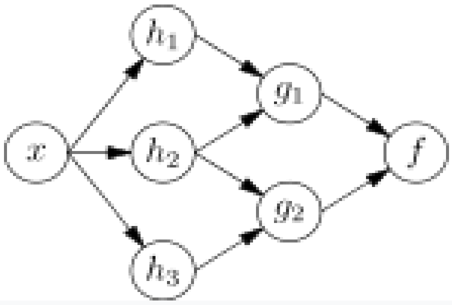
3. CAPACITIVE LOADING IN PIFA ANTENNAS

In this technique, we add capacitance to the PIFA antenna, between the feed point and the open edge.

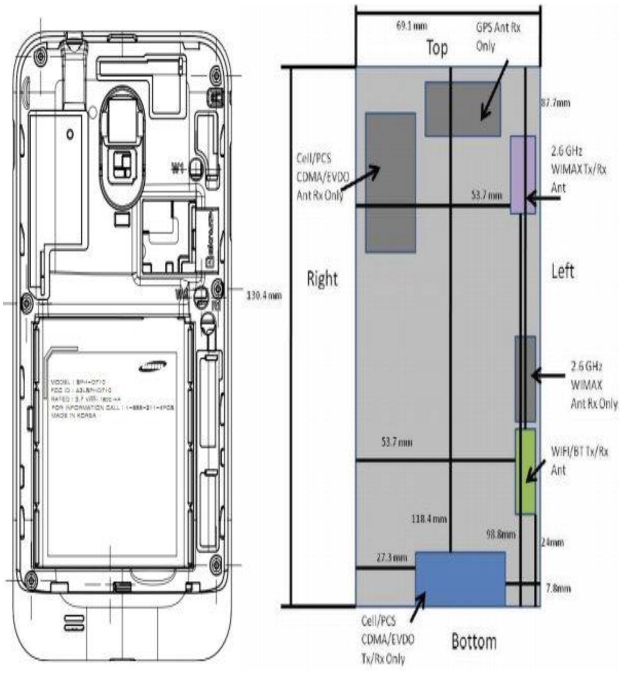


PIFAS in the Real World

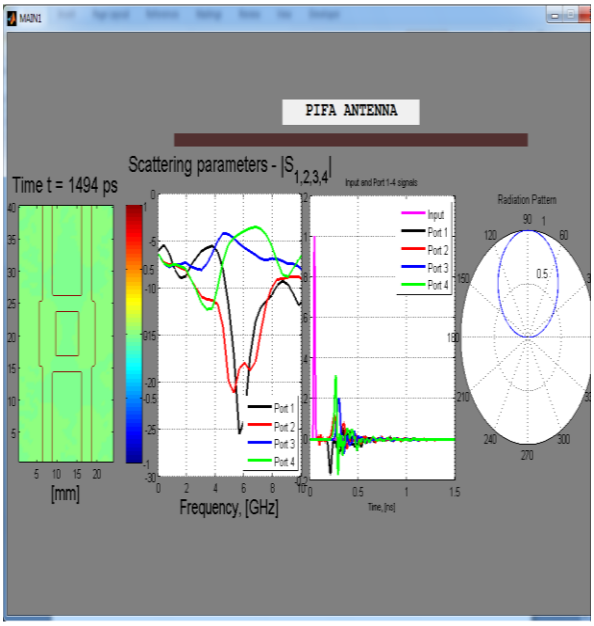
The Samsung Galaxy S is an android smartphone that works on CDMA networks in the US. This means the frequency will be 850 and 1900 MHz, requiring one transmit/receive antenna and one receive-only antenna (known as a diversity antenna). The phone's antennas have been shown in an FCC report, shown below: The antenna types and locations on the Samsung Galaxy S.



ANN dependency graph



4. SIMULATION RESULT



5. CONCLUSION

In this project, a novel compact triple band PIFA has been proposed. It is seen that by creating slots on top patch, it exhibits triple resonance behavior. A KBNN model is used for the modeling of the ripple band PIFA. The model is based on RBFN and BPN. Low % error and high accuracy in less time are achieved by this method. The results obtained using this method is in good agreement with the simulation results. It can give very good predictive results for relatively small training data sets, even in the presence of multiple design variables. This method offers an accurate and efficient alternative to previous methods for modeling of antennas. This method is not limited to the resonant frequency computation of PIFA. It can easily be applied to other antennas and other microwave engineering problems.

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