Compact Super Wide Band Monopole Fractal Antenna for Wireless Communication

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Abstract: A compact fractal monopole antenna using Functional Section Design is proposed for super wideband (SWB) communication. The proposed antenna is of size $55 \times 55 \text{mm}^2$. It is designed using CST microwave studio simulation software. This antenna has been fabricated on FR4 substrate of dielectric constant 4.3 and tested with Vector Network Analyzer. The antenna has super wide bandwidth up to 30 GHz with measured peak gain variation from 1 to 6 dBi and omnidirectional radiation pattern. This antenna is useful in many of the wireless communication systems. Recently fractal antennas have been used as invisibility cloaks, and as fundamental new antenna ‘fractal collar slip-on’ technology.

Introduction

Modern communication system needs an antenna which has small size and broad bandwidth to cover short as well as long range transmission. There are simple planar microstrip antennas which can cover entire super wide band (UWB) range from 3.1-10.6 GHz, but they have drawback of short range communication due to low gain. Nowadays, there is extensive demand of SWB antennas which can be used in multiple wireless communication systems. The term SWB means decades of bandwidth. SWB antenna should provide the impedance bandwidth of at least 10GHz with the 10-dB return loss according to the present requirement [1]. SWB technology is a crucial part of modern wireless applications in civilian and military systems. Designing a cheap and small size antenna with super wide characteristics is a difficult task. Microstrip antennas are good for achieving compact size and broad bandwidth but they are efficient radiators up to 1/4 wavelength size only afterwards there gain and radiation efficiency deteriorate. Fractal is very good solution to this problem, with self similarity and space filling abilities fractals can achieve multiple bands with good efficiency [2]. The discontinuous shape of fractal improves bandwidth and effective radiation of antenna. Space filling property of fractals helps in size reduction of patch. The self similarity of fractal accounts for multiband and broadband characteristics. [3-4]. Some papers have been published on SWB designing using different geometries [3-9] on SWB antenna. For examples, a super wideband fractal antenna of size 35mm x 35mm is presented in [3] using fractal generator. Compact design of SWB of size 29 mm x 45 mm is presented in [4]. UWB antenna by using Sierpinski carpet and Giusepe Peano fractal is presented in [5]. A monopole antenna by adding a semi-elliptical slot into the ground plane is presented in [6] but the structure of this antenna is large and complex. A circular SWB antenna with bandwidth ratio of 20:1 is reported in [7]. Semi-elliptical patch antenna with CPW fed is presented which has 19.7GHz impedance bandwidth. Functional section design approach for SWB antenna design is presented in [8]. The FSD approach focuses on dimensions as parameters and keeps them small so that optimization gets easier.

1. Design of Proposed Antenna

1.1. Antenna Topology

In the starting, antenna topology has to be selected. For that UWB antenna which has been designed previously is selected. This antenna is made of four starred fractal iteration inside the circular patch. Equations for designing circular patch are as follows:

$$r = \frac{\frac{2h}{f} \left[ \ln \left( \frac{1}{f} \right) + 1.7726 \right]}{1 + \frac{2h}{f} \left[ \ln \left( \frac{1}{f} \right) + 1.7726 \right]}^{1/2}$$

Where,

$$f = \frac{8.791 \times 10^9}{fr\sqrt{\varepsilon_{eff}}}$$

1.2. FSD Approach

In super wide band antenna design as the fractal iterations are increased there is significant increase in bandwidth. But there are fabrication constraints as well as complications in designing due to which infinite number of iterations can’t be used. To
Improve the bandwidth further Functional Section Design approach is used.

Figure 1 FSD logical sections

FSD is the bottom-up strategy. It starts from the feed section. CPW feed produces the omni directional radiation pattern. Then comes internal radiation section. It is inserted as a lower patch in between the patch and the feed for, impedance matching, resonance shifting and also as independent optimized parameter. The shape is chosen logically and then optimized. Next is main radiating section serves as patch of the antenna. This section is made circular or round at the edges so as to get good radiation pattern. In this paper topology chosen is itself circular so no need to add extra ground edges in to the patch. These sections are orderly numbered as I, II, III

1.3. Parameter Identification and Optimizations:

I: Feed section- For planer antennas Coplanar Waveguide (CPW) fed is used. CPW has advantages over Microstrip fed such as low dispersion at high frequencies, omni directional radiation pattern, and easy integration with devices etc.
II: Internal Radiating transition Section- Two parameters, which are key components of this section, are size and position of the added internal transition patch. The radius is optimized to its best. The shape is chosen according to the patch section for smooth transitioning from feed to patch.
III: The External Radiating Patch Section- In this section two circles of same radius as of internal transition circle are added to the patch. This forms the symmetry in the patch designing and gives smooth omni directional radiations.

2. Results and Discussions

The proposed antenna is circular Microstrip antenna with iterated fractal inside. The circular shape is chosen in-between rectangle and circle since it gives smaller patch size as compared to a rectangular shape at the same frequency. Also, there is only one parametric dependency that is radius whereas in the case of the rectangle we have to control length as well as width.

The simulation has been performed using CST microwave studio. All those parameters mentioned above are optimized using this software. Teflon substrate is selected as middle conductor of CPW fed to achieve 50 ohm impedance at the port. As we vary the sections (I, II, III), impedance bandwidth gets affected heavily. The prototypes shown below give impedance bandwidth in the SWB range. Prototype of SWB antenna is as shown in the fig. 2

The simulation results of return loss of antenna is as shown in the fig.4, here; first resonant frequency shift is due to the change in overall effective patch size of respective prototype. For both prototypes we get good return loss i.e. less than -10 dB up to 30 GHz. Calculated VSWR are as below in fig.5. From fig.5 it is clear that antenna has required VSWR that is less than 2 throughout the super wide band.

The simulation result of return loss of SWB final design is as shown in above. Here; the first resonant
frequency is due to the patch size. As we lower the size of inner circles the frequency shift occurs towards higher side. Ground length and feed line are selected critically because they provide impedance matching to the antenna. The ground modification has a considerable effect on improving return loss. Calculated VSWR is as below in Fig.4. From this fig, it is clear that antenna has correct VSWR that is less than 2 throughout the super wide band.

![Figure 4: VSWR (simulated)](image)

This antenna offer very good super wide bandwidth from 1.8 GHz to 30 GHz. The simulated and measured results are similar but not exact. This may be because of defect in manufacturing, uncertainty of the dielectric constant of the substrate and poor of SMA connector. Also, soldering of SMA connector leads to variation in experimental results. Radiation patterns evaluated at various frequencies are as shown. From these patterns we can see that antenna is Omni directional in azimuth plane.

![Figure 5: Radiation pattern at a) 6.6GHz b) 23.1GHz](image)

3. Conclusion

This paper presents work on analysis and design of SWB fractal antenna. Two major performance characteristics are taken into consideration for designing, return loss & bandwidth. The operating band depends on patch size and overall size of the antenna. The proposed SWB antenna covers almost entire super wide band 1.8 to 30 GHz. Drawback i.e. reduced gain for the broadband antenna has been overcome by using fractal structure and gain improvement of 2-3 dB has been achieved. Radiation pattern of antenna is omni directional. Proposed antennas have been simulated on CST studio software and fabricated on cheap substrate FR4. The experimental results of the antenna exhibit good match with simulated results.

4. Future Scope

The time domain analysis of these antennas to test the reliable signal transmission/reception can be performed along with the calculation of their impedance bandwidth. Overall size reduction of the antennas and improvement in return loss can be achieved using RTduroid material as a substrate. Time Domain Characteristics of Micro strip Antenna (for primitive antenna, antenna with single band-notch characteristics, antenna with dual band-notch characteristics and antenna with triple band-notch characteristics) can be investigated.

4. References


