Abstract
Adaptive Antenna for iBurst Modem was designed and constructed. iBurst is a wireless broadband Internet technology available in Australia which operates at 1.9 GHz. It is basically an end to end technology which works on SDMA (Space Division Multiple Access). Adaptive Array Technology is not a single Antenna but a set of Antenna Elements arranged in space and the outputs are multiplied by some weights and summed up. Design of Antenna which is Auto Steerable having a Broad Beamwidth, Compact, Cheap, Self Aligning, High Gain and Vertically Polarized was done. Finally Adaptive Antenna design was done on HFSS and came up with two designs Cylindrical Shaped and Semi Octagonal Shaped. There are two versions of cylindrical designs. These designs consist of one Monopole in the centre with four Parasitic Elements around. Simulation was done by making one of the Element Active at a time. Simulation Results shows the Return Loss at 1.9GHz. Return Loss of the designs are 11dB, 11.5dB and 18dB respectively for Design 1, Design 2 and Design 3. The 10dB Band width of designs is 300 MHz, 200 MHz and 100 MHz respectively. Similarly the Radiation plots and 3D Plots of these designs gives nice big Front lobe and small back lobe with front to back ratio of 5dB, 4.5dB and 9.9dB respectively and 3dB Beam width of 1200, 1200 and 900.

Keywords
iBurst, adaptive antenna, SDMA

I. Introduction

A. What is iBurst ?
iBurst is a wireless broadband technique through which high quality, high speed broadband internet can be accessed anywhere within the region of iBurst network range with in Australia. It is an upcoming technique which is presently available in some parts of Australia but with the increasing popularity it will be used by 75% of people and 90% of business within few years [2].

“The main objectives of iBurst are:
1. Coverage
2. Penetration
3. Capacity
4. Mobility
5. Portability

Technology
It works on 1.9GHz which is a privately owned frequency, which is not effected by 802.11. “It is a wide area mobile broadband technology which offers a unique combination of high speed, wide range and high base station capacity.”

It is basically an end to end technology having a base station and a wireless modems where the base station is like that of mobile communication. Base stations are deployed by network operator, wireless modem are used to access the system.
“Normally, the term “antenna” comprises only the mechanical construction transforming free electromagnetic (EM) waves into radio frequency (RF) signals travelling on a shielded cable or vice versa. In the context of “Adaptive Antenna” the term “antenna” has an extended meaning.” Here it is a phased array in which set of antenna elements are arranged in space and the outputs are multiplied by some weights and summed up. Complete array is one antenna with one summed output. The summed output is summed in both space and amplitude and it depends on the weights applied to the signals and their position in space. The weights are varied with time depending on the signal which is done by a control unit. The control unit is adaptive antennas intelligence which is realized by Digital Signal Processing (DSP). [1, 4, 7]

C. SDMA (Spatial Division Multiple Access)

SDMA (Space Division Multiple Access) is the technology which is derived from Adaptive Array Technique i.e. it is using the space domain for the communication. In this multiple communications can be made at the same frequency. If we consider three users communicating with the same base station within same frequency (A, B & C) each will have the mutual interference of the other but with phase and amplitude adjustments it is avoided, while having the link with A the signals of B and C are suppressed which makes the efficient use of frequencies and increase base station capacity also [3].

SDMA is the most advanced technology for utilizing data from antenna arrays. It can be used to multiply the capacity given by the conventional techniques such as FDMA, TDMA or CDMA. This technique exploits the space domain. With this technology used with adaptive array antenna at the base station the antenna become highly directive to the user. With the exploitation of space domain in this multiple users can communicate within one frequency channel with base. If we consider one more combiner to the outputs of antenna as used in Adaptive Antenna but the weights of second combiner are chosen as that they will eliminate the signal from mobile 1 and only optimises the signal from mobile 2. In this way communication with two mobiles at single conventional channel, be it frequency, time, or code is possible. This is SDMA. Theoretically m elements can support m spatial channels per conventional channel. Practically the efficiency of the system depends on capabilities of adaptive and characteristics of the channel i.e. channel assignment strategies, traffic scenarios, beam forming and properties of radio channel. [1, 5]

The capacity of system can be increased by reducing the channel reuse pattern as interference due to co-channels is reduced as by using 4-cell reuse instead of 7-cell pattern or by the intra cell use of conventional channels. It is compatible with all types of modulation techniques.

Benefits of SDMA

- Range Extension- the coverage area of the array is increased due to the increased gain of the array and reduction in the number of cells for a given area by using SDMA. As in a 10 element array the gain is 10 which doubles the range of cell and quadruples the coverage area.
- Interference caused by the other systems and other users in the area is reduced and in noisy areas communication is possible due increase in range of the system due to SDMA.
- The multipath fading is also reduced. [5]

D. Link Adaptation

Link Adaptation is the technology which provides ideal digital modulation techniques to the signal depending on its quality. It provides high speed modulation for strong signals and low speed modulation to signals when they become weak in order to prevent dropping of signals. This also increases the mobility. “The variable range is eight increments for uplink and nine for downlink.” [3]
II. Adaptive Antenna

Auto Adaptive Antennas also called as Smart antennas have some key benefits:

- They automatically seek out the optimal base station signal.
- They continuously adapt to changes.
- They are user friendly as you just install them, you don’t have to know about the location of base station.
- They easily switch beams.
- Tracking at angular change rate, No reference signal required.
- No calibration required.

In case of Yagi antenna, knowledge of the location of the base station is necessary in order to have the maximum signal strength for both wanted and unwanted signal. Whereas in the case of Adaptive Antenna it automatically scans through the angles to align itself to base station to have maximum signal strength.

So the aim is to make a prototype of an Auto Adaptive External Antenna for iBurst desktop modem in order to boost up the signal strength [13].

Switched Parasitic Antennas offer directional patterns. The concept is to use a single active antenna element with one or several passive antenna elements operating near resonance. These passive elements are called Parasitic Element (PE) and act together with the active element to form an array to alter the radiation pattern. The termination impedances of the Parasitic Elements are switchable to change the current flowing in those elements. They become reflectors when shorted to the ground plane and when not shorted they have little effect on the antenna characteristics.

Switched parasitic element is a promising answer for such a design as it is able to steer itself in azimuth. These parasitics act as directors or reflectors as in the case of Yagi-Uda design. Central driven element is basically a monopole which is being fed.

Out of four parasitic elements one is shorted with the ground plane to get a beam. Here element is acting as reflector instead being a director to the monopole element.

Considering the design there are lot of parameters to be looked at for getting design at 1.9 GHz.

Parameters to be considered while simulating the designs were:

- Number of Parasitic Elements
- Length of Parasitic Elements
- Width of Parasitic Elements
- Radius of Antenna
- Radius of Monopole
- Height of Monopole
- Dielectric Constant of the Material used to support Parasitic Elements
- Thickness of the Material used to support Parasitic Elements

While designing the monopole instead of taking a whole cylinder, a combination of Cylinder and Cone was used in order to get a pointed structure which would give easiness in construction of the prototype.

III. Proposed Antenna design Procedure

It is basically a switched parasitic antenna design having four parasitic elements in a circle which are supported by a cylindrical structure having a metal driven element through a finite ground plane.

The antennas were simulated by using HFSS (High Frequency Structure Simulator) which a 3D simulator is utilizing the Finite Element Method (FEM) to solve for the electromagnetic field. The software was used to calculate the far-field radiation pattern of the antenna for different settings of the switched parasitics.

Monopole was fed through the lumped port. Even the parasitics were designed for steering both 1800 and 3600 which finally gave three designs out of which two are versions of 3600 steering and one is of 1800.

In order to get Reflection Coefficient of the designed antenna at 1.9 GHz and desired Radiation Pattern simulation has to be done repeatedly by varying the parameters discussed above. Simulation setup for testing of antenna consists of lumped port for feeding to monopole, as parasitic elements are basically spline which are extended and exited as perfect E Boundary so that they act as perfect conductor or metal.

As said earlier testing for radiation pattern is done for farfield, so farfield setup has to be done for \( \alpha = 3600 \) and \( \beta = 3600 \) in form of sphere. Radiation boundary has to be there at \( \lambda/4 \) distance from the antenna. For the analysis, design has to be fast or discrete sweep for frequency range from 1GHz to 2.5GHz with the Adaptive Frequency 1.9 GHz with 10 Passes and 0.02 Delta S.

After repetitive simulation results two designs were finalized out of which one is for 3600 steering and other one is for 1800 steering. These designs were named as Cylindrical Design and Semi Octagonal Design respectively. [15]

A. Cylindrical design

This design is a 3600 steering design. This has two versions of designs with nearly similar dimensions and just few differences in the dimensions.

Dimensions of Design 1

- Height of Antenna = 44 mm
- Outer Radius of Antenna = 21.25 mm
- Inner Radius of Antenna = 18.75 mm
- Height of Centre Lobe
  - Cylinder = 29 mm
  - Cone = 4 mm
- Radius of Centre Lobe
  - Cylinder = 4.5 mm
  - Cone Higher= 4.5mm
  - Lower= 1.5 mm
- External Patch Size
  - Width = 10 mm
  - Height = 20 mm
- Thickness of Ground Plane = 1.5 mm

Fig. 8: Design 1
Dimensions of Design 2

Dimensions of Design 2

- Thickness of Ground Plane = 1.5 mm

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Height of Antenna = 44 mm
Outer Radius of Antenna = 21.25 mm
Inner Radius of Antenna = 18.75 mm
Height of Centre Lobe Cylinder = 29mm
              Cone = 4mm
Radius of Centre Lobe Cylinder = 3 mm
              Cone Higher = 3mm
              Lower = 1mm
External Patch Size Width = 4 mm
Height = 20mm
Thickness of Ground Plane = 1.5 mm

Fig. 9: Design 2

**B. Semi Octagonal Design / Design 3**
In this design a metal wall was considered in the back which acts as mirror to the monopole and the parasitic elements as directors.

Height of Antenna = 39.9 mm
Thickness of Antenna Structure = 1 mm
Size of Antenna X Axis Semi Octagonal = 40 mm
              Cuboid = 25 mm
              Y Axis = 80 mm
Height of Centre Lobe = 30mm
Radius of Centre Lobe = 3 mm
External Patch height = 15 mm
Thickness of Ground Plane = 1 mm

Fig. 10: Design 3

**IV. Simulation Design and Results**

**A. Return Loss S11**

Fig. 11: S11 in Design 1

Fig. 11 is S11 Plot of Design 1. It shows the return loss of the antenna is 11dB at 1.9 GHz, which is the desired Frequency. As in this case requirement of the antenna with good return loss and at the required Frequency is fulfilled. Also its 10 dB Band width is from 1.78 GHz – 2.08 GHz i.e. around 300MHz. This Antenna is performing over quite a wide band width, which is a promising Result.

Fig. 12: S11 in Design 2

Similarly in this design which is S11 Plot of Design 2 Return Loss of the antenna is 11.5 dB at 1.9 GHz, which is the desired Frequency. This antenna also fulfills the requirement of good Return loss at the required frequency. Also its 10 dB Band width is from 1.85 GHz – 2.05 GHz i.e. around 200MHz. This Antenna is performing over quite a wide band width, but less than the earlier one even then it is a promising Result.

Fig. 13: S11 Design 3

In this design which is S11 Plot of Design 3 Return Loss of the antenna is 18 dB at 1.9 GHz, which is quite good at the desired Frequency. This antenna also fulfills the requirement of good Return loss at the required frequency and also its 10 dB Band width is from 1.85 GHz – 1.95 GHz i.e. around 100MHz. This Antenna is performing over quite a wide band width, but less than the earlier ones.

**B. Radiation Pattern**

Fig. 14: Radiation Pattern of Design 1
Fig. 15: 3D Plot of Design 1

Fig. 14 and Fig. 15 shows the radiation pattern of Design 1 of Cylindrical antenna in 2D and 3D respectively. By comparing the design and the Radiation Pattern it shows that the Shorted Parasitic Element is acting as Reflector to the Feed Element/ Monopole in the centre. Maximum Radiation is toward 900 and that is just opposite to the Shorted Patch. It has a wide 3dB beam width of 1200. It shows a big Front lobe and a small back lobe with
Front to Back Ratio = 10dB-5dB = 5dB

Fig. 16: Radiation Pattern of Design 2

Similarly, Fig. 16 and Fig. 17 show the simulated Radiation Pattern of Design 2 of Cylindrical Antenna. These patterns are similar to that of Design1 showing big front lobe and small back lobe and here also on comparing the radiation Pattern with design it shows that the Shorted Parasitic Element act as Reflector with a Maximum Radiation at 900 and having a wide 3dB beamwidth of 1200.
Front to Back Ratio = 10dB-5.5dB = 4.5dB

Fig. 17: 3D Plot of Design 2

Fig. 18 and 19 shows the Radiation Pattern of Design 1 when two Parasitic Elements are Active. It clearly shows that when two Elements are active then the radiation is at an angle through them. As the maximum Radiation is at 1500 which is opposite to the Parasitic Elements which shows that the parasitic Elements are acting as Reflectors and having a big Front Lobe with a small back lobe. 3dB beamwidth of the Pattern is 1000 and Front to Back Ratio is =18dB-5dB=13dB.

Fig. 18: Radiation pattern of Design 1 with two Parasitic Elements Active

Fig. 20: Radiation pattern of Design 2 with two Parasitic Elements Active

Similarly Fig. 20 and 21 shows the Radiation Pattern of Design 2 when two Parasitic Elements of the design are Active. It clearly shows that when two Elements are active then the radiation is at an angle through them. As the maximum Radiation is at 1400 which is opposite to the Parasitic Elements which shows that the parasitic Elements are acting as Reflectors and having a big Front Lobe with a small back lobe. 3dB beamwidth of the Pattern is 1000 and Front to Back Ratio is =18dB-8dB=10dB.

Fig. 21: 3D Plot of Design 2 with two Parasitic Elements Active
Fig. 22: Radiation Pattern of Design 3

Fig. 23: 3D Plot of Design 3

Fig. 22 and Fig. 23 shows the Radiation Pattern and 3D Plot of Design 3 or Semi Octagonal design. In this case Radiation pattern shows that the Shorted Parasitic Element is acting as director to the monopole. It shows Big Front lobe and very small Back lobe. Maximum Radiation is at 1700 with 3dB beamwidth of 900. Here Front to Back Ratio = 13.9dB - 4dB = 9.9dB

C. Antenna Properties

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<th>Property</th>
<th>Design 1</th>
<th>Design 2</th>
<th>Design 3</th>
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Radiation Efficiency is coming more than 1 in case of Design 1 and Design 2 and nearly Equal to 1 in Design 3. This is because in the design instead of taking metals, perfect conductors are used so there is no loss.

After observing the Design Parameters and Simulated results it can be said that the need of Adaptive Antenna having broad beam width, compact, mobile, cheap, self installing, high gain and vertically polarized durable could be fulfilled with these designs. Here Design 1 and Design 2 are designs which are steering in 360° and Design 3 steers itself in 180°.

V. Conclusion

The Purpose of this research is to design an Adaptive, Auto Steerable, Broad Beamwidth, Compact, Cheap, Self Aligning and High Gain Vertically Polarized Antenna for iBurst Modern which is one of the Broadband Wireless Internet Provider in Australia. YagiMax and NEC were utilized to design and simulate them. Yagi Antenna was designed on YagiMax with different trials for the required frequency which is 1.9GHz. The Design got through the YagiMax was simulated using NEC and the performance was observed.

The aim for designing an external antenna for iBurst Modern was finally successful after designing the Adaptive Antennas. Adaptive antenna is promising solution for the problem of Multipath Fading as it will act as both Directional and Omnidirectional antenna depending on the Coverage of the network switching its Parasitic Elements/Element as required. These work with adaptive antennas intelligence which is realized by Digital Signal Processing (DSP).

These Designs were designed and Simulated on HFSS. Looking at the proposed designs it could be said that these designs are easy to construct, compact, cheap and mobile. There are two versions of Cylindrical Shaped Design and one Semi Octagonal Design.

Simulation of the designs with one of the Parasitic Element Active shows the Return loss of the antenna the desired Frequency which is 1.9GHz. Return Loss of the designs are 11dB, 11.5dB and 18dB respectively for Design 1, Design 2 and Design 3. These design got a broad 10dB Band width of 300 MHz, 200 MHz and 100 MHz respectively.

Similarly the Radiation plots and 3D Plots of these designs gives nice big Front lobe and small back lobe with front to back ratio of 5dB, 4.5dB and 9.9dB respectively and 3dB Beam width of 1200,1200 and 900. Simulation of Design 1 and Design 2 with two adjacent Parasitic Elements active shows the Radiation in the required Direction.

VI. Acknowledgment

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References

Nitin Kathuria received his B.E. degree in Electronics & Communication from J.T. Mahajan College of Engineering, under North Maharashtra University in 2004, the M.E. degree in Communication & Information from Griffith University, Brisbane, Australia, in 2007. He was lecture with Department of Electronics & Communication, Teertahnker Mahaveer University, Moradabad in 2009-10. Presently he is an Assistant Professor in Department of Electronics & Communication at NOIDA Institute of Engineering & tech., Grater NOIDA, UP, India. His research interests include Antenna Design & Microwave Engineering. At present, He is engaged in Ultra Wideband Antennas.