# DBF ASIC Measurements and Application

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## Abstract

Satixfy had been developing a chipset for a fully digital wideband beamforming antenna array. The structure and architecture of the chip was and of a full array based on it was presented in [1]. The performance and limits of such an antenna array taking into account actual implementation were presented in [2], analyzing the errors and impairments introduced by various effects, and shows the feasibility of a fully digital design for a variety of applications in the satellite communication field. In this paper we present measurement results of an antenna using the actual production chips, as well as a new AERO antenna, based on the chip set.

## 1. Introduction

Near-future mobile wireless communications require high data rate systems with virtually, worldwide coverage. Due to the insufficient coverage provided by terrestrial networks, high data rate services are usually not available in remote areas, or on board of ships and airplanes. Satellite communications (SatCom), and more specifically SatCom on-the-move (SOTM) are thus key in achieving high-capacity communications with a global coverage. With recent explosion in large capacity wireless access systems demanding high spectral efficiencies, array antennas have now assumed great significance in radio and wireless communication system. Multi-Input Multi-Output (MIMO) antenna arrays has now become an integral part of the standards for cellular and wireless local area networks in current and future generations. These active antenna arrays will play an equally important role in next generation high throughput-satellite (HTS) communications. Also, with introduction of large LEO and MEO constellations being planned by companies like OneWeb, O3b and SpaceX, there will be a growing need for antennas at ground terminals tracking multiple satellites. The parabolic dish antennas have been de-facto satcom earth antenna thus far because of mostly fixed pointing for GSO applications. These antennas have their advantages from cost and power consumption but also are extremely inflexible and have lower efficiencies. On the other hand, electronically steerable antennas are active scanning antennas that provide many benefits viz self-installation capabilities, multi-satellite communication and satellite tracking. Payloads can be made more flexible and enable techniques such as multibeam, beam hopping and flexible beam shaping. All – electronic control removes the need for moving mechanical parts, which are slow and more prone to malfunctions. At the present time, Ku-band capacity is widely available among the existing geo-stationary satellite networks already orbiting the planet, hence, increased interest has been addressed to satellite services at Ku-band, namely, digital TV broadcast, broadband internet services, internet-of-things (IoT), etc. The success of these services however, will depend on the development of new high performance and low-cost user terminals, with the ability of tracking the satellite position while in motion. More specifically, the antenna employed, must be capable of very wide-angle scanning whilst keeping the fabrication costs as low as possible, as most applications apply to mass consumer markets. For low cost applications such IoT, cost of antenna can be further reduced by using energy efficient waveforms such as half-duplex which optimize the link and resource utilization. Cost impact of such a waveform can be realized by designing single antenna that can serve both as Rx and Tx.

To meet those cost-reduction requirements, Satixfy had been developing a chipset for a fully digital wideband beamforming antenna array. The structure and architecture of the chip was and of a full array based on it was presented in [1]. The performance and limits of such an antenna array, taking into account actual implementation, were presented in [2], analyzing the errors and impairments introduced by various effects, and shows the feasibility of a fully digital design for a variety of applications in the satellite communication field.

The paper is organized as follows: Section 2 of the paper introduces the Systems Architecture showing an integrated architected antenna system. This is followed by brief description of beam-former and RF transceiver ICs in Sections 3 and 4. In section 5, an L-band (1-2GHz) antenna electronically steerable antenna system that is controlled directly by digital beamformer is described along with radiation pattern measured in Small Anechoic Test Range. These measurements are compared with theoretical measurements that shows good alignment between the two.

## 2. System Architecture

Figure 1 shows Satixfy's fully integrated antenna terminal system with respective interfaces. The Digital beamformer which is at the heart of the electronically steerable antenna is connected to the Up/Down Converter (Beat) via Analog I,Q interface and to the Satixfy's Sx3000 Modem via high speed digital bus interface (SerDes). This tight integration allows highly configurable, responsive and controlled antenna for different applications. Satixfy's digital beamformer and Ku band RFIC are explained briefly in section 3 and 4.

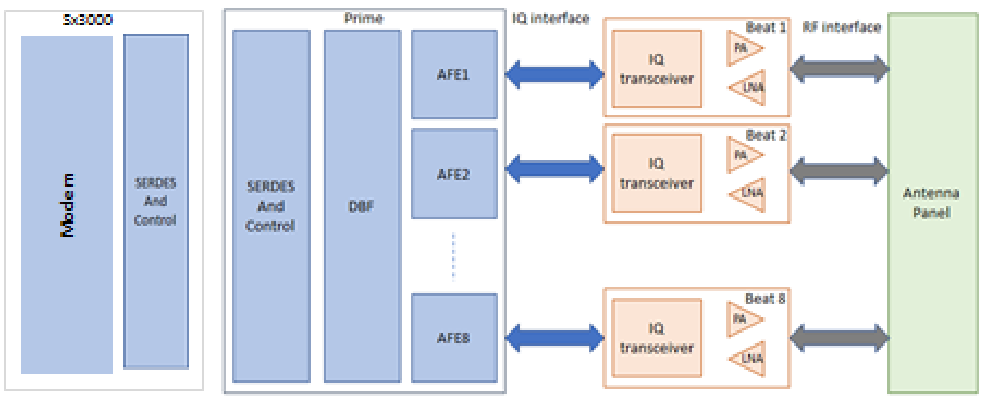



**Figure 1** – System Architecture

## 3. Digital Beamformer

The DBF chip (Prime) can digitize each antenna element as it contains several high-speed ADCs and DACs which connect externally (via several RF transceiver) to the antenna panel elements. The connection between DBF and the RF transceiver is via a high BW IQ interface. Within each DBF, the ADCs/DACs are connected to several high-resolution digital phase shifters and digital delay circuit which implements True Time Delay [1] as shown in Figure 2 to avoid beam squints for wideband signal transmission/reception. The DBF chips are connected to each other and to the Satixfy's Sx3000 modem by high speed digital serial bus (SerDes) which allows for a highly integrated and scalable antenna system. Some of the key features of the DBF are listed below:

- Over 1GHz Instantaneous Signal Bandwidth Full Multibeam Capability (up to 32 beams)
- Analog baseband interface (up to 2GHz) for RFIC
- Tight integration with Satixfy's Sx3000 using High Speed Digital Interface (SerDes)
- Support for external modem via L-band interface
- Very high-speed beam tracking /beam steering (orders of magnitude better than mechanical solution) Polarization Control (Linear and Circular) Self-Calibration capability with built in Synchronization Engines, Antenna Control Unit integrated with Satixfy Sx3000 modem
- Multibeam Transceiver (upt o 32 beams), with independent phase, gain and delay control for each beam
- Equalization/Pre-Equalization and Digital Predistortion per beamformer chain

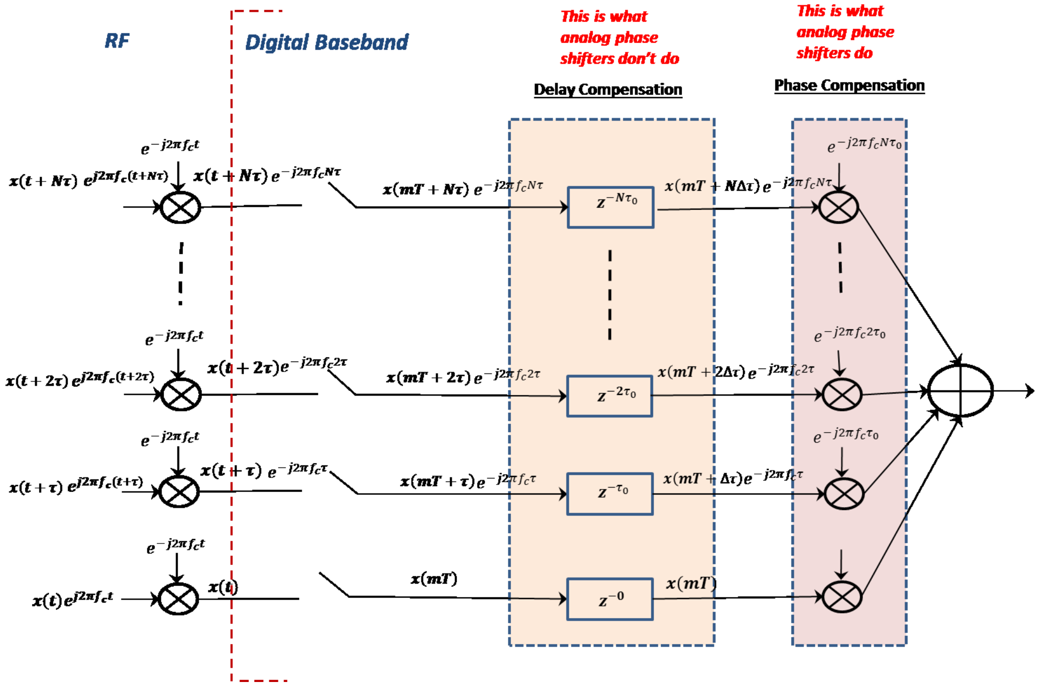
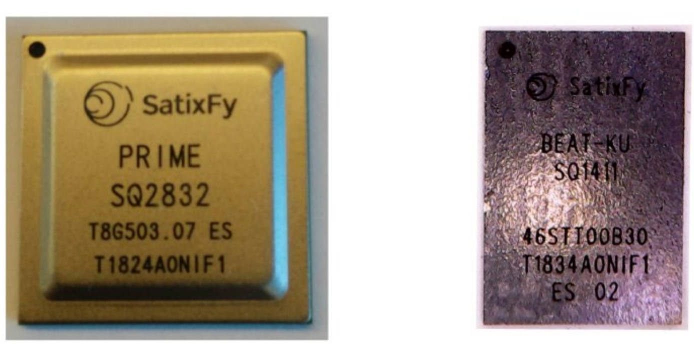



**Figure 2** – Mathematical Description of True Time Delay [2]

## 4. Satixfy's RF Transceiver

The RF transceiver contains both an up-converter and down-converter which link the Digital Beam Former IQ signals with the Ku band antenna elements. The upconverter and down-converter are using a direct conversion architecture with broadband IQ mixers. The chip features electronic polarization control and supports both linear and circular polarization. In combination with the Digital Beam-Former the up-converter supports Digital Pre-Distortion. The down-converter features a very low noise integrated RF front end capable of receiving very weak signals. A single Beat has up/down converters for 4 Ku antenna elements and can support Rx and Tx in Half Duplex configuration.




(a) Beam-former. (b) RF Transceiver.

**Figure 3** – Satixfy's Antenna Chip-sets

## 5. L-Band Test Antenna Array

In-order to test and demonstrate the capabilities of the Prime ASIC, we developed a 6x6 (36 element) L-band (1-2 GHz) antenna array, which was directly controlled by DBF (Prime) chip on an evaluation board. Each Prime chip can support up to 32 elements. For 36 elements, two Prime standalone evaluation boards were connected by high speed digital interface called SerDes. 24 of the 36 elements were supported on one board and the remaining 12 elements were connected to second Prime evaluation board. The system was completely synchronized to demonstrate the modularity of architecture that allows building larger antenna by daisy chaining the DBF chips.

For measurements on the Near-Field Range in TX-Mode, an Anritsu Spectrum Analyzer was used as shown in Figure 4, in an Anechoic chamber. The setup comprised of circularly polarized 6x6 L band antenna array that was put together by using the commercially available off-the-shelf antenna elements, which when put in an array, half a wavelength away, measured mutual coupling less than -20dB. The antenna bandwidth was only 5MHz. A single omni-directional L-band antenna element was used as Receiver antenna. which was connected to the spectrum analyzer to record the power measured. The Tx Array was mounted on a 3-D positioner which can move in both the elevation and azimuth planes. It was placed 3.75m away from the Rx antenna. The distance means that the receiver was right at boundary of Radiating Near field and Far field. The center of both Tx array and Rx array were aligned.

Before measuring the radiation pattern of the Tx array, all the elements needed to be calibrated for both phase and gain to get an optimum starting point. This calibration sequence involved using one of the central elements of Tx Array as a reference and was done for boresight. The calibration routine was optimized for time and was conducted in a way that the subarray calibrated was in far field. In other words, for beamforming and beam-steering we were using far field calibrated phase offsets, that were determined with <1-degree inaccuracy with the help of high resolution digital phase shifters, and applying in radiating near field. For phase calibration CW tones were used, which were generated from within the DBF chip. After calibration, the beamformed signal showed almost close to theoretical gain of 31dB (within 0.5dB) compared to single element.

For generating the radiation pattern, 3 CW tones were used separated in frequency by 400kHz. The three beams were spatially separated and pointing at boresight ($0^o$), $+27^o$ and $-27^o$ and the power measurements recorded simultaneously. Figure 5 shows the normalized radiation pattern obtained from the lab measurements which matches very close to the theoretical pattern, especially for the main lobe and the 1st sidelobes. Even though the Anechoic chamber setup was not suitable for L-band measurements, the results of the test were extremely positive with radiation pattern showing accurate beamwidths ($16.67^o$ for boresight and $18.7^o$ for $+/-27^o$) and sharp nulls.

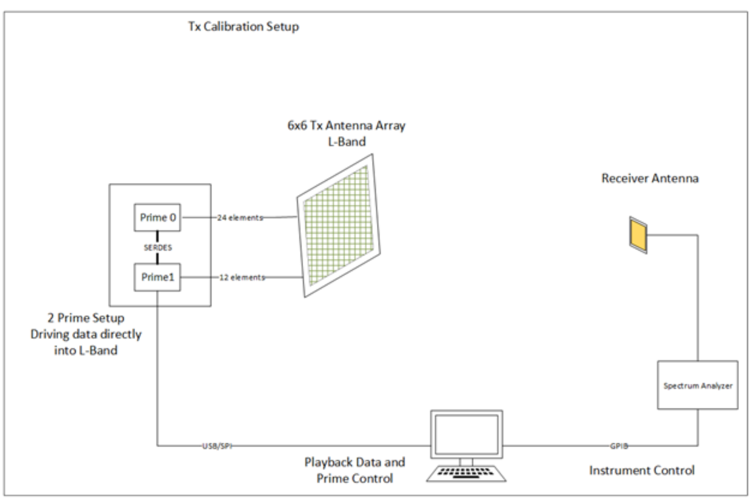



**Figure 4** – Test setup for Anechoic Chamber

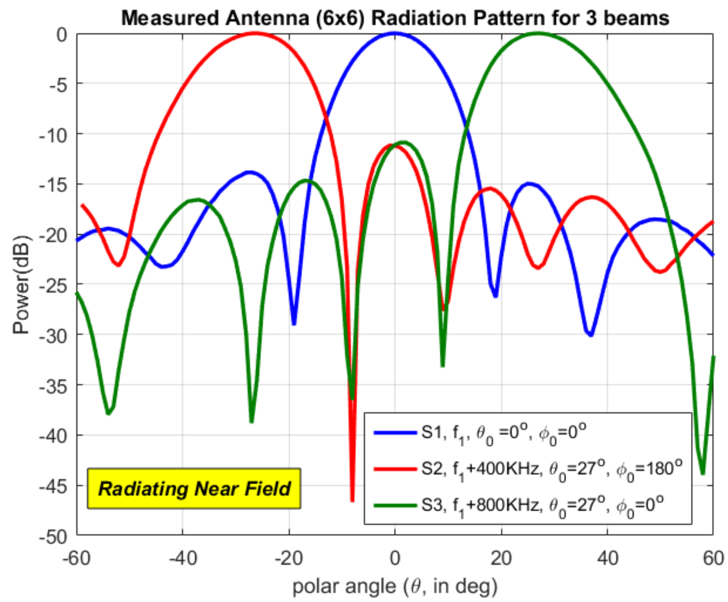



**Figure 5** – Measured Radiation Pattern for 3 beams simultaneously

## 6. Conclusion

In this paper, we introduced Satixfy's Digital Beamformer (Prime) and Ku band RFIC chip (Beat). Initial results using the Prime ASIC as a Digital Beamformer were shown in this paper. More details and results in Ku band will be provided in the future. The initial results were showing ease of calibration, synchronization, control and high-resolution shifters for beamforming, and most importantly - industry first multi-beam features are extremely positive and is a prelude to wide range of applications that Prime and the electronically steerable antenna will service.

Satixfy is currently engaged in developing a half-duplex IoT terminal using self-diplexing antenna and Ku Beat and Prime, the results for which will be showed in the future.

We expect the digital beamforming will pave the path for unlocking digital beamformer's full potential that can address the future needs of tracking antennas for high throughput satellite communications with cost advantage offered by silicon economics.

## 7. References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