Multi-Tone Millimeter-Wave Frequency Synthesizer for Atmospheric Propagation Studies

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Introduction

Introduction - Motivation

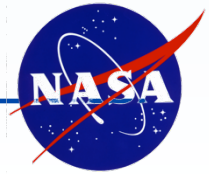
- Growing user community has resulted in increased congestion in the traditional Ku, K, and Ka frequency bands designated for space-to-ground data communications
- The next available bands for satellite downlinks above Ka-band are the Q-band (37-41 GHz) and E-band (71-76 GHz)

Introduction - Advantages

- Advantages of Q-band & E-band over Ka-band for data transmission
  - To be competitive with terrestrial fiber optic and wireless services, broadband satellite providers need to reduce the cost per transmitted bit. This can be attained by increasing satellite total throughput. At Q-band and V-band the allocated bandwidth is in excess of 4 GHz, which can enhance satellite throughput by 10X or higher
  - Narrower beam width and smaller spot size for a given antenna size
  - Smaller spot size enables greater frequency reuse and spectral efficiency
  - Other U.S. Government Agencies have interest in the large available bandwidth at E-band

Introduction – Problem Outline

- ★ Lack of rigorous studies to understand the atmospheric effects on radio waves propagation at Q-band & E-band frequencies. These studies are essential for the design of a robust communications system for deployment in space
- ★ To conduct such a study a beacon transmitter at Q-band and E-band frequencies have to be deployed on a satellite and statistical data on rain attenuation, fading, change in the refractive index, scintillation, de-polarization effects, etc., have to be acquired over 3 to 5 years with ground receivers dispersed over climate zones of interest



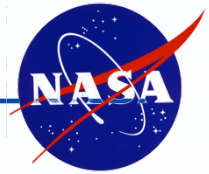
Introduction – Potential Solutions

- ★ SSPA Based Beacon Transmitter and Antenna System
  - ✧ Design of a feasible Q-band beacon transmitter and antenna system was presented at the 2012 IEEE Inter Symposium on Antennas & Propagation, Chicago, IL

- ★ ALPHASAT – Telecom Satellite for Technology Demonstration
  - ✧ Scientific experiment payload: Q-Band Beacon (39.402 GHz, EIRP: 26.6 dBW, Global Horn antenna) and a Ka-Band Beacon (19.701 GHz, EIRP: 19.5 dBW, Global Horn antenna) (3 spot beams) (Launched by ESA in July 2013)

Introduction – Potential Solutions (continued)

- Single-Band Multi-Tone Beacon Transmitter can be Constructed with a High Frequency Solid-State Comb Generator



Introduction – Potential Solutions (continued)

★ The Solid-State Comb Generator Based Beacon has the Following Features:

- ✧ The spectrum comprises of evenly spaced harmonic frequencies of the input signal, which are coherent & tunable over a wide frequency range
- ✧ Harmonics can be amplified to the power level needed for radio wave propagation studies
- ✧ Harmonics that are amplified can be simultaneously transmitted as beacon signals from space to receiving stations located at climate zones of interest within the CONUS
- ✧ By measuring the the signal relative strength and phase at ground sites one can estimate the attenuation and group delay or dispersion due to atmospheric induced effects

Rational for Multi-Band Multi-Tone Frequency Synthesizer

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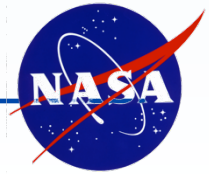
- Significant amount of statistical data has been accumulated since NASA's pioneering ACTS experiments of the 1990's and accurate models that predict the impairments to radio waves in the 20/30 GHz bands due to Earths atmosphere are available
- Communication satellites systems are currently operational at these frequencies
- It is well understood that signals at Q-band and E-band frequencies would experience much higher attenuation during rain fades than signals in the 20/30 GHz range
- The deep fades will result in poor signal-to-noise ratio at the Q-band and E-band beacon receivers on ground, which could cause the receivers to lose frequency/phase lock

- ★ Hence it is desirable to include a coherent K-band (18-26.5 GHz) beacon source on the payload
- ★ Because of higher signal-to-noise ratio at K-band, the beacon receiver on ground can retain lock during deep fades and thus enable availability attenuation measurements
- ★ This data is valuable and can provide a reference for model development and also provide an understanding of frequency scaling factors for future system design when Q-band and E-band propagation data is unavailable



Discussions & Conclusions

Conclusions & Discussions

- The design, construction and test data for K-band, Q-band, and E-band multi-tone frequency synthesizer for radio wave propagation studies through the Earths atmosphere is presented