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
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 Earth’s 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 Earth's atmosphere is presented.