MILLIMETER-WAVE PHASED-ARRAY FOR BROADBAND WIRELESS APPLICATIONS

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INTRODUCTION.

License free frequency bands are available in the USA, Canada, Japan, and Europe that cover most of the 57 - 65 GHz spectrum. The portion of this band in the US alone is about one hundred times the size of the 2.4 GHz wi-fi band and thereby offers a revolutionary improvement in terms of available bandwidth and data rates for broadband wireless communications. Such a wide frequency range can be used to alleviate situations where bandwidth may be scarce and be used for wide bandwidth applications including real-time video, data streaming and enterprise cloud computing . Wireless propagation in the vicinity of 60 GHz however, results in high signal attenuation of between 10 - 20 dB/km due to the atmosphere.

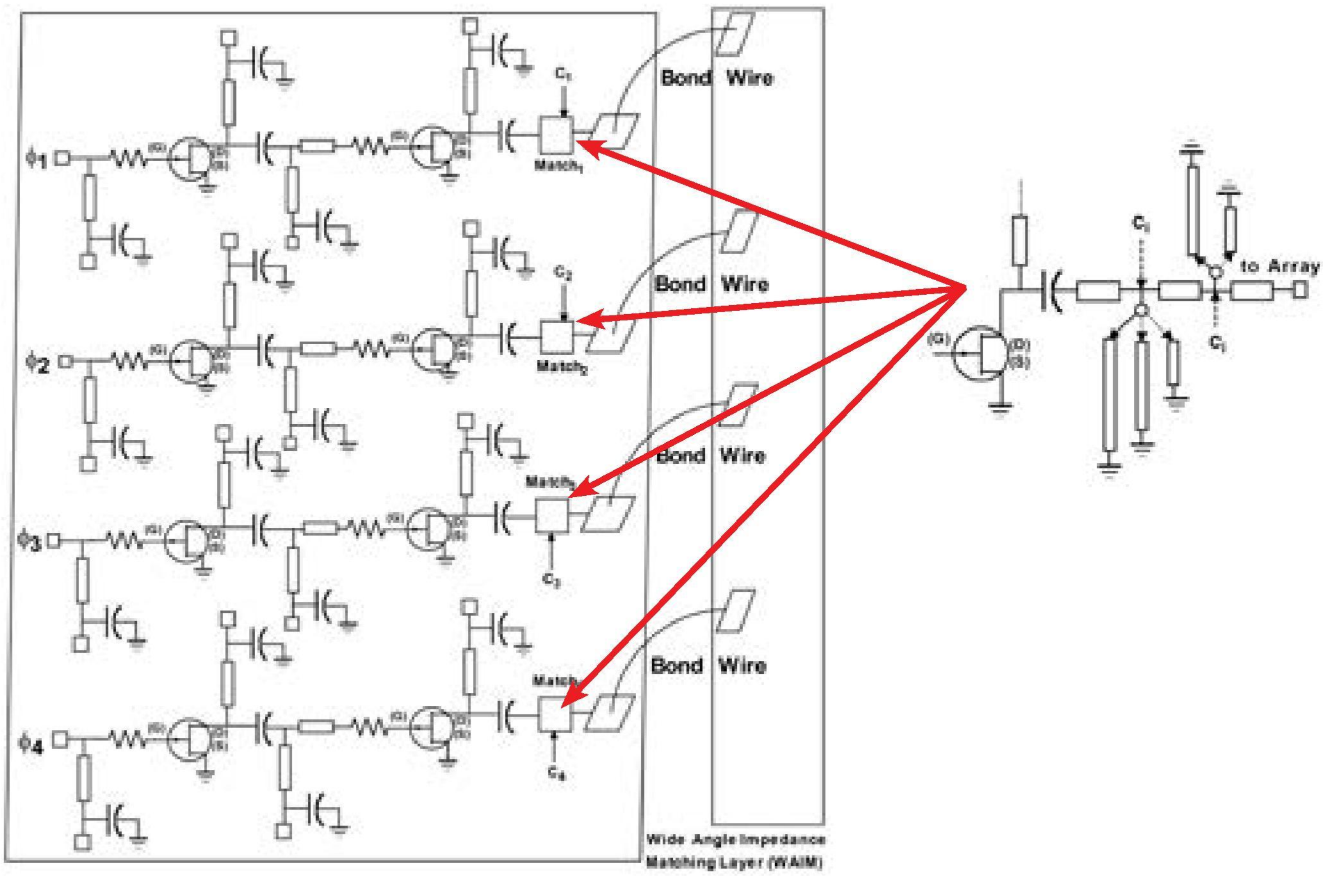

Figure 1. *Tunable MMIC Amplifier Array.*

METHODOLOGY.

Atmospheric attenuation can have both advantages and disadvantages. The advantages are that high attenuation can result in a physical barrier between users resulting in higher security against unintended interception of signals and the effects of multipath from buildings and other structures are minimized. The presence of multipath can result in an increase in delay spread of the received signal which limits data rate and bandwidth. Higher attenuation also helps to isolate cellular sites providing for better frequency re-use in a cellular base station environment. The disadvantage is higher attenuation of the radiated signal.

One way of mitigating the effect of high atmospheric attenuation is with a phased - array antenna. A phased-array produces a highly directional antenna pattern having high gain in a preferred direction. Since the wavelength in free space at 60 GHz is only 5 mm, the footprint for an array will be physically small e.g. a 10 x 10 array occupies only about one square inch. Also, since the output power at 60 GHz from commercially available semiconductors is limited, the phased array provides a simple way of spatially combining the output powers from multiple active devices for higher total radiated power. A limitation with phased array antennas is the variation in output power with the scan angle due to the electromagnetic coupling between adjacent antenna elements. When the scan angle of the array is varied, the phase of the power coupled between adjacent antenna elements also varies causing the input impedance to each antenna element to change causing reflections and thereby decreasing the total output radiated power. This impedance is variable with scan angle since the power coupled between adjacent elements varies due to the changes in phase of the excitation of the array elements. Active impedance refers to the impedance seen at the input to each antenna element by the output of the power amplifier with the adjacent elements also excited and varies as a function of scan angle and frequency.

The main objective of this research is to integrate wideband 60 GHz GaAs monolithic microwave integrated circuit [MMIC] technology, phased-array antenna techniques to produce wideband, high power, high data rate RF front end for multi-Gigabit mixed signal processing wireless applications. Higher output power is achieved by matching the output of each amplifier in the array nearer to the active impedance seen at the input to the radiating element over scan angle and frequency and by fabricating the active devices using Gallium Arsenide (GaAs) instead of CMOS semiconductors. The active impedance varies with scan angle because power coupled from adjacent elements in the array into the radiating element varies due to the resulting phase change in the excitation used to scan the array pattern. The input impedance to the radiating element varies depending on the radiating element location in the array for any given scan angle and frequency. An important design consideration is to control or limit this impedance variation and resulting variation in output power delivered from the amplifiers (Fig. 1). Higher output radiated power is necessary to overcome atmospheric attenuation in particular for non line of sight conditions at 60 GHz. GaAs MMIC technology provides (i) higher breakdown voltage resulting in higher output power and, (ii) lower loss substrates resulting in higher quality passive components e.g. MIM capacitors and spiral inductors over Silicon and Silicon-Germanium based technologies.

CONCLUSIONS.

Typical scenarios for application of this technology are shopping malls, airports, convention centers, and dense urban settings and situations where a large number of users transmit and receive large amounts of data. This includes real-time video and cloud computing. For non line of sight situations having the presence of multipath, each antenna of a Smart or MIMO (multiple-input, multiple-output) antenna, e.g. upcoming 5G system, could be a phased array to increase capacity.