A Mixed-Signal Row/Column Architecture for Very Large Monolithic mm-Wave Phased Arrays

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ABSTRACT

While mm-wave radio communications offer $1 - 10\ \mathrm{Gbit/s}$ rates, range is severely constrained by high $P_{received}/P_{transmit} = (D_t D_r/16\pi^2)(\lambda/R)^2 e^{-\alpha R}$ losses arising from the short wavelength and from atmospheric attenuation. Large antenna directivities D enable large range R but, unless antennas are fixed, require electronic beam steering. With N-element transmit and receive arrays, $D \sim \pi N$, while $P_{transmit} \propto N$ due to array power-combining, hence $P_{received} \propto N^3$. Using 32×32 arrays ($N \sim 1000$), link SNR is increased $\sim 90\ \mathrm{dB}$ permitting e.g. $10\ \mathrm{Gbit/s}$ *mobile* communication over a long $\sim 1\ \mathrm{km}$ range even in heavy rain [1]. Unfortunately, it is difficult to realize large arrays using present monolithic beamsteering IC architectures [2], [3].

We propose an alternative architecture for large monolithic phased arrays (Fig. 1). The beam is steered in altitude and in azimuth by separately imposing vertical and horizontal phase gradients. These phase gradients are applied and summed by mixing the IF or baseband I/Q signal first against a vertical array of phase-shifted LOs and subsequently against a horizonal array of phase-shifted LOs. The number of LO buses and phase selectors grows as $\sim 2N^{1/2}$, not N. IC complexity is reduced, making large arrays feasible.

Extensive digital processing provides robust amplitude control and reduces die area. The LOs are processed as digital signals using ECL selectors and propagated using transmission-line bus drivers and buffers as repeaters (Fig. 5). Mixers, as ECL XOR gates with degeneration added on the IF ports for IF-RF linearity, interface directly to the ECL LO signals (Fig. 4). The IF signals must not compress and are processed as analog signals; avoiding area-inefficient reactively-matched subcircuits, the first and second IF signal buses absorb their periodic gate loading capacitance into synthetic transmission-line buses, similar in design to a distributed amplifier (Fig. 3). Signal routing between IC and printed-circuit antennas follows a Manhattan geometry to maintain the desired phase distributions.

REFERENCES

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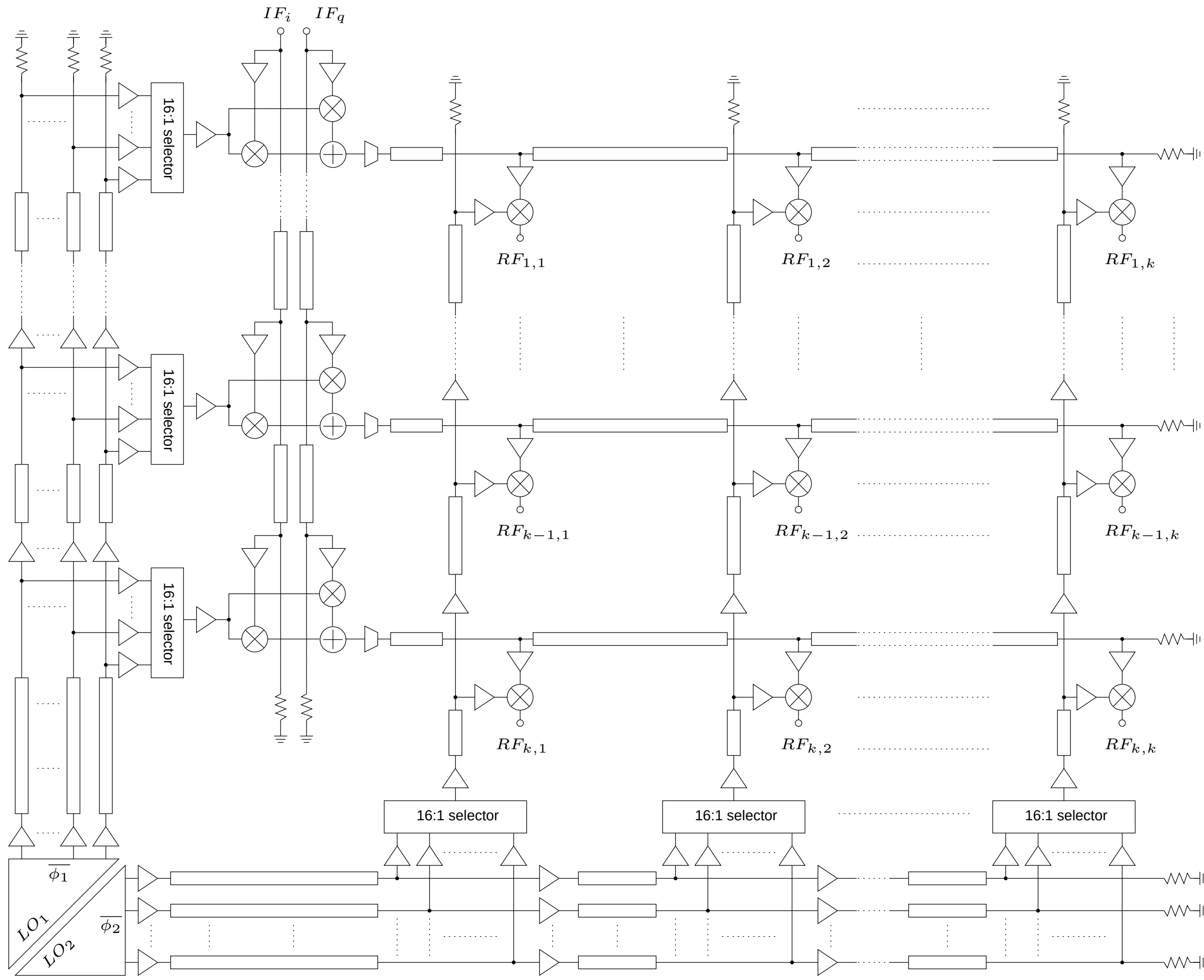

Fig. 1. System architecture of a large monolithic phased array.

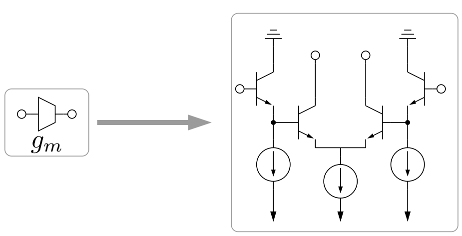

Fig. 2. Area-inefficient reactively-matched subcircuits are avoided in the IF paths.

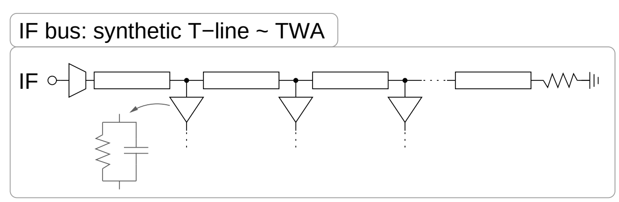

Fig. 3. IF signal buses absorb their periodic gate loading capacitance into synthetic transmission-line buses.

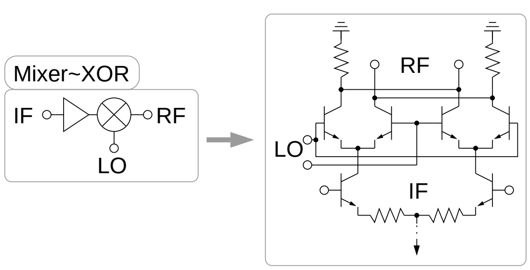

Fig. 4. Mixers, as ECL XOR gates, interface directly to ECL LO signals.

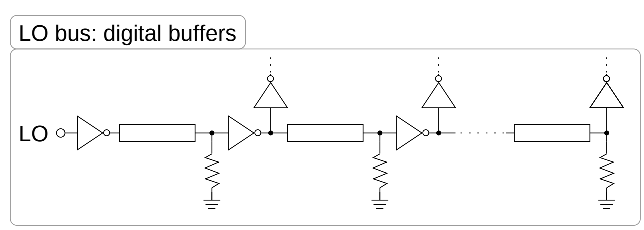

Fig. 5. LOs are processed as digital signals.