XX. CIRCUIT THEORY AND DESIGN*

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A. PRIME-NUMBER MULTIPLIER CHAINS

High-order frequency multipliers often consist of a chain, or cascade, of lower-order multipliers, usually doublers or triplers. Thus, for example, a × 24 circuit could be made as a cascade of three doublers and a tripler. But what if the desired harmonic number is a prime? An ordinary cascade cannot be used. We show in this report how the concept of multiplier chains can be extended slightly to allow generation of all high harmonics (prime and nonprime) by cascading individual stages.

Let us examine in a fundamental way the generation of the harmonic. An input at frequency ω_o is used to excite the nonlinear device. The nonlinearities force this signal to mix with itself and power is generated at the sum frequency $\omega_o + \omega_o = 2\omega_o$. This second harmonic, if allowed to exist, mixes again with the fundamental to form the frequency $\omega_o + 2\omega_o = 3\omega_o$, or with itself to form $4\omega_o$. The process is one of mixing a signal either with itself or with another signal.

Now suppose that instead we introduce two input frequencies (each a harmonic of some fundamental) and let them mix with each other. The output is taken at the sum (or difference) frequency, which can be a prime multiple of the fundamental. Approximately as much power can be generated at this output frequency as could be delivered by a multiplier with the same nonlinear element. What we have described is a "power upconverter" (or "power downconverter"). To generate a large prime number, we can use two multipliers or multiplier chains to generate two nonprime harmonics whose sum is the desired prime, and then mix the outputs from these two chains in a power upconverter.

For example, consider the generation of the fifth harmonic. This can be generated at high efficiency with idlers at $2\omega_o$ and $3\omega_o$, or with idlers at $2\omega_o$ and $4\omega_o$. It can also be generated, however, by mixing the outputs from a tripler and a doubler, or by mixing the output from a chain of two doublers with the fundamental, or even by mixing the output from a chain of a doubler and a tripler with the fundamental. Thus, the quintupler (and other multipliers) can be built either with idlers or as a cascade of simpler multipliers and power upconverters.

Power upconverters made from abrupt-junction varactors[1] can have efficiencies and power outputs that are comparable to those of varactor multipliers, and they are designed by using very similar techniques.

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Power upconverters (and downconverters) should be considered possible components in multiplier chains. With this slight extension of the concept of "multiplier chain," chains can be built to generate any harmonic, prime or nonprime, and the designer of multipliers is somewhat less restricted in his choice of frequencies.

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References

1. P. Penfield, Jr. and R. P. Rafuse, Varactor Applications (The M.I.T. Press, Cambridge, Mass., 1962), Chapter 10.