Modulating the HF signal

This document discusses an idea for improving the accuracy of HF modulated waveforms for which the amplitude is not constant. This involves the phase shifting circuitry, and so its operation is summarized first, beginning with a signal with no modulation, just a sinusoid.

When an unmodulated signal is transmitted, a sinusoidal wave at the exact required rf frequency is generated and input to the phase shifting circuitry that generates the correct signal for each of the six transmitters. Call this signal $x(t)$, and so in this case $x(t) = \cos \omega t$, or $x(t) = \Re(\exp j\omega t)$, where j is the square root of -1, and Re means "real part of", and ω is the frequency of the transmitter in radians/sec. There are six phase shifters, and each consists of a balanced mixer where the local oscillator input is $x(t)$, and the $\sin$ and $\cos$ inputs are dc values $\sin \phi_i$ and $\cos \phi_i$, where ϕ_i is the required phase shift for the ith transmitter. This pair of values is represented in complex form as $\exp(j\phi_i)$. The signal from the ith phase shifter is the real part of

$$s_i = \exp(j\omega t)\exp(j\phi_i) = \exp(j\omega t + \phi_i)$$

if $x(t)$ is not a perfect sinusoid, then it has some finite bandwidth, and the phase shifts required for proper operation of the array are no doubt somewhat different at the different frequencies. But this is not a big effect with a narrowband signal, and the antenna array functions well enough and everything is fine as long as x(t) is a phase or frequency modulated sinusoid, but not if it is amplitude modulated. This is because $x(t)$ is fed to the local oscillator (LO) input of the phase shift mixers, and this input is not linear.

In order to fix this problem, pass the (sinusoidal or non-sinusoidal) $x(t)$ through a baseband mixer where the complex LO is $\exp(-j\omega t)$, where ω is the center or carrier frequency associated with $x(t)$. The result of this operation is $x_b(t) = x(t)\exp(-j\omega t)$, a narrowband signal. It is a complex signal, and it can be shifted in phase by a complex multiplication Thus, the phase shift for the ith transmitter can be implemented from the signals that we have, and so $x_{bi}(t) = x(t)\exp(-j\omega t)\exp(j\phi_0)$. In the real world this complex multiplication requires four multipliers. (The Analog devices MLT04 has four multipliers on a chip for under $20.00.) The final step is to put this complex signal into the balanced modulator that we already have in the circuit, and we connect the carrier frequency to its LO input, (We multiply by $\exp(+j\omega t)$ to accomplish this.) Then $x_i(t) = x(t)\exp(j\phi_i)$, and the real part of this is the signal that we need for the ith transmitter.

In the real world we could generate the complex baseband signal directly without the baseband mixer, but since we already know how to make those signals we need with signal generators that we have, it seems that directly following the math above with the circuit is a good way to proceed. However, we do not have to generate the signal at the actual carrier frequency we will use, but could use a convenient reference frequency such as 10 MHz. The resulting baseband signal is the same as long as the 10 MHz signal is used in the baseband

mixer. This would make it easier to use the same signal for 5.1 or 8.175 MHz. Of course, the phase shift mixers would use the current carrier frequency as their LO.
Also, it might be that some signal we need in the future would be most conveniently generated at baseband as a pair of real signals. Thus, it would be a good idea to provide baseband inputs as well as an rf input.

The baseband signal is not wide band, essentially covering the audio range. Thus it can be easily filtered with op amps using Rs and Cs..