Novel applications in microwave communication systems
for small-shift frequency translators

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Abstract

With the present revival of the heterodyne modulator and the comparatively recent introduction of the microwave I-Q vector modulator, novel applications in multiple access communication systems are proposed which are ideally suited for these high performance small-shift frequency translators. Sub-systems for performing frequency hopping and frequency division multiplexing are described.

I. Introduction

Small frequency translation are traditionally required in modern microwave measurement and radar systems. Examples include: homodyne vector network analyser [1], frequency scanning antennas and velocity detection ECM systems [2]. However, there are possible applications for small frequency translations in microwave communications systems.

A frequency translator, employing a conventional mixer, usually requires an output filter. As the required frequency translation is reduced, the Q-factor of the filter must increase, in order to adequately attenuate only the unwanted sidebands generated by the inefficient mixing process. A point is reached when the frequency translation is equal to the bandwidth of the signal to be translated. At this point, only a theoretical "brick-wall" filter could be considered. Beyond this point, there will be inherent distortion due to spectral overlap.

In practice, small frequency translations can only be performed using either a non-mixing sinusoidal modulator or a heterodyne modulator. With both techniques, the generation of significant unwanted sidebands can be avoided - therefore, improving RF power efficiency (enabling a conversion loss of 0dB) and removing the need for an unrealisable filter. In addition, the unwanted sideband suppression is not normally a function of the input RF power level.

The sinusoidal modulator simply introduces a continuously linear change, with time, in its insertion phase. An increasing change causes a positive frequency translation, by an amount which is proportional to the rate of change. Conversely, a decreasing change causes a negative frequency translation. Non-mixing sinusoidal modulators have been realised using a mechanically rotating dielectric stub, rotating magnetic field, balanced diode modulator and I-Q vector modulator.

The heterodyne modulator is a derivative of the sinusoidal modulator. Here, a klystron, TWI or phase shifter is modulated with a sawtooth waveform, such that one period of the sawtooth results in an induced phase shift which linearly sweeps through an entire multiple of 360°. For a 360° phase shifter, the amount of frequency translation is equal to the repetition rate of an ideal sawtooth waveform. The direction of frequency translation can be changed by simply inverting the sawtooth profile.

II. Novel Applications

2.1. Frequency Hopping

Frequency hopping in code division multiple access (CDMA) communication systems can be easily performed with small-shift frequency translators, as illustrated in Fig. 1.

In both the frequency hopping transmitter and receiver, the translator removes the need for an elaborate frequency synthesiser/detector filter arrangement, thus, saving on complexity and cost.

2.2. Heterodyne Frequency Division Multiplexing

Frequency division multiplexing in frequency division multiple access (FDMA) communication systems is also an ideal application for small-shift frequency translation, as illustrated in Fig. 2.
With the implementation of transistors, $N$ channels or $N$ groups of channels can be frequency multiplexed without the need for $N$ highly stable carrier generators or a frequency synthesizer. The proposed solution provides a high degree of modularity, since only the low frequency signal generators (within the frequency translators) are different, offering low complexity and low cost. A frequency division demultiplexer can be realized in a similar way to the multiplexer.

2.3. Homebased Frequency Division Multiplexing

With homodyne digital modulation techniques there are no IF stages -- modulation by the baseband signal is performed directly at carrier frequency (3-7). This technique offers the advantage of simplicity, over the more conventional heterodyne techniques. Also, baseband filtering may be employed, for spectral sidelobe suppression, in preference to the less power efficient and more expensive method of using high-Q microwave filtering.

Direct M-PSK modulation can be implemented with an I-Q vector modulator. A relatively complicated realization of a QPSK modulator has been reported using this technique (5). However, direct M-PSK-modulation can be implemented much more simply by using a 360$^\circ$ phase shifter (4) and small-shift frequency translations can be performed with a monostable modulator (5). Therefore, if a number of M-PSK channels are to be multiplexed, it follows that the same phase shifter could be used to perform the phase modulation and frequency translation -- by combining the control signals.

Similarly, direct M-QAM modulation can be implemented with an I-Q vector modulator. A relatively complicated realization of a 64-QAM modulator has been reported using this technique (6). However, direct M-QAM modulation can be implemented with a much simpler I-Q vector modulator design (7) and small-shift frequency translations can be performed with a non-mixing sinusoidal modulator. Therefore, if a number of M-QAM channels are to be multiplexed, it follows that the same simple I-Q vector modulator can be used to perform the magnitude/phase modulation and frequency translation -- again, by combining the control signals.

The discrete and integrated implementations of these PSK/FDM and QAM/FDM scenarios are illustrated in Fig. 3.

III. Conclusions

Three novel applications in multiple access communication systems have been proposed for small-shift frequency transistors. It is believed that such transistors can be used to achieve high levels of performance, while minimising hardware complexity and cost.

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References

Figure 1: Frequency hopping CDMA architecture

Figure 2: Frequency division multiplexer architecture

Figure 3: Homodyne digital modulation architectures