# Armstrong Indirect FM Transmitter

Example 4

Figure 4.11 shows the simplified block diagram of a typical FM transmitter (based on the indirect method) used to transmit audio signals containing frequencies in the range 100 Hz to 15 kHz. The narrow-band phase modulator is supplied with a carrier wave of frequency $f_1 = 0.1$ MHz by a crystal-controlled oscillator. The desired FM wave at the transmitter output has a carrier frequency $f_c = 100$ MHz and the frequency deviation $\Delta f = 75$ kHz.

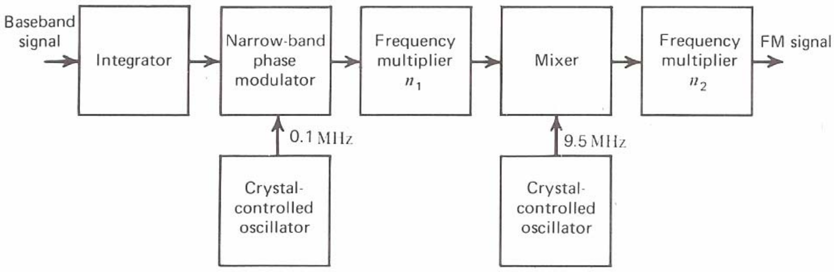


**Figure 4.11** Block diagram of the wide-band frequency modulator for Example 4.

In order to limit the harmonic distortion produced by the narrow-band phase modulator, we restrict the modulation index $\beta_1$ to a maximum value of 0.3 radians. Consider then the value $\beta_1 = 0.2$ radians, which certainly satisfies this requirement. The lowest modulation frequencies of 100 Hz produce a frequency deviation of $\Delta f_1 = 20$ Hz at the narrow-band phase modulator output, whereas the largest modulation frequencies of 15 kHz produce a frequency deviation of $\Delta f_1 = 3$ kHz. The lowest modulation frequencies are therefore of immediate concern.

To produce a frequency deviation of $\Delta f = 75$ kHz at the FM transmitter output, a frequency multiplication is required. Specifically, with $\Delta f_1 = 20$ Hz and $\Delta f = 75$ kHz, we require a total frequency multiplication ratio of 3750. However, using a straight frequency multiplication equal to this value would produce a much higher carrier frequency at the transmitter output than the desired value of 100 MHz. To generate an FM wave having both the desired frequency deviation and carrier frequency, we therefore need to use a *two-stage frequency multiplier* with an intermediate stage of frequency translation, as illustrated in Fig. 4.11. Let $n_1$ and $n_2$ denote the respective frequency multiplication ratios, so that

$$n_1 n_2 = \frac{\Delta f}{\Delta f_1} = \frac{75{,}000}{20} = 3750 \qquad (4.46)$$

The carrier frequency at the first frequency multiplier output is translated downward in frequency to $(f_2 - n_1 f_1)$ by mixing it with a sine-wave of frequency $f_2 = 9.5$ MHz, which is supplied by a second crystal-controlled oscillator. However, the carrier frequency at the input of the second frequency multiplier is equal to $f_c/n_2$. Equating these two frequencies, we get

$$f_2 - n_1 f_1 = \frac{f_c}{n_2}$$

Hence, with $f_1 = 0.1$ MHz, $f_2 = 9.5$ MHz, and $f_c = 100$ MHz, we have

$$9.5 - 0.1 n_1 = \frac{100}{n_2} \qquad (4.47)$$

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This example is extracted from Communication Systems *by* Simon Haykin Second Edition

**Table 4.2.** Values of Carrier Frequency and Frequency Deviation at the various Points in the Frequency Modulator of Fig. 4.11

| | At the phase modulator output | At the first frequency multiplier output | At the mixer output | At the second frequency multiplier output |
|---|---|---|---|---|
| Carrier frequency | 0.1 MHz | 7.5 MHz | 2.0 MHz | 100 MHz |
| Frequency deviation | 20 Hz | 1.5 kHz | 1.5 kHz | 75 kHz |

Solving Eqs. (4.46) and (4.47) for $n_1$ and $n_2$, we obtain

$$n_1 = 75$$
$$n_2 = 50$$

Using these frequency multiplication ratios, we get the set of values indicated in Table 4.2.