RF Modems — Part I

Part I provides an introduction to the subject of RF modems and covers designs for single channel units.

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RF modems provide a means of relaying digital data between two locations by modulating/demodulating a rrier signal. In this sense they are like ..iore common modems that interface to telephone networks. For telephone line modems, however, the carrier signal frequency lies within the audio range (<3 kHz) while for RF modems the carrier signal falls in the RF spectrum and is typically transmitted via the airways or a broadband coaxial cable similar to that used in CATV networks. RF modem carrier frequencies to over 400 MHz are practical for cable systems and operation to over 100 MHz is quite common. RF modems offer high data rates and the simultaneous use of many channels (one per RF carrier employed) and are frequently used in distribution systems and CATV networks.

The maximum data rate and number of operating channels required of an RF modem varies with the application. In some cases a single channel (or a transmit/receive channel pair) is sufficient. In other applications a multi-channel modem is required. The term "frequency agile" is used to describe modems that can be programmed to operate on various channels or carrier frequencies. In addition to being a key cost determining factor, the data rate also establishes bandwidth requirements for each RF channel d thus sets the maximum number of ..iannels possible within a given system bandwidth. For example, 6 MHz of system bandwidth might be used to accommodate approximately 20 to 60 low data rate (64 Kbit) channels or two high data rate (approximately 1.5 to 2.5 Mbit) channels.

The Basics

The major functions of a frequency agile RF modem and its associated digital interface are given in Figure 1 along with ICs (also see Inset) useful for their implementation. The digital interface provides the necessary system control and data processing but is normally not considered as part of the RF modem itself.

The modem in Figure 1 can be programmed to operate on one of many RF channels via the channel code provided to the channel control function. This is accomplished by making the channel control function a phase-locked-loop (PLL) RF frequency synthesizer. A synthesizer controls both the transmitter's RF output signal frequency and the receiver's local oscillator or mixer injection signal frequency. The local oscillator signal dictates what RF channel the receiver will respond to. Depending on the degree of transmitter/receiver channel flexibility required, one or two PLL synthesizers may make up the channel control function. Also, in some design approaches, the data to be transmitted (T_X data) may also be applied to the program input of the PLL that is controlling the transmit channel frequency (dashed connection in Figure 1).

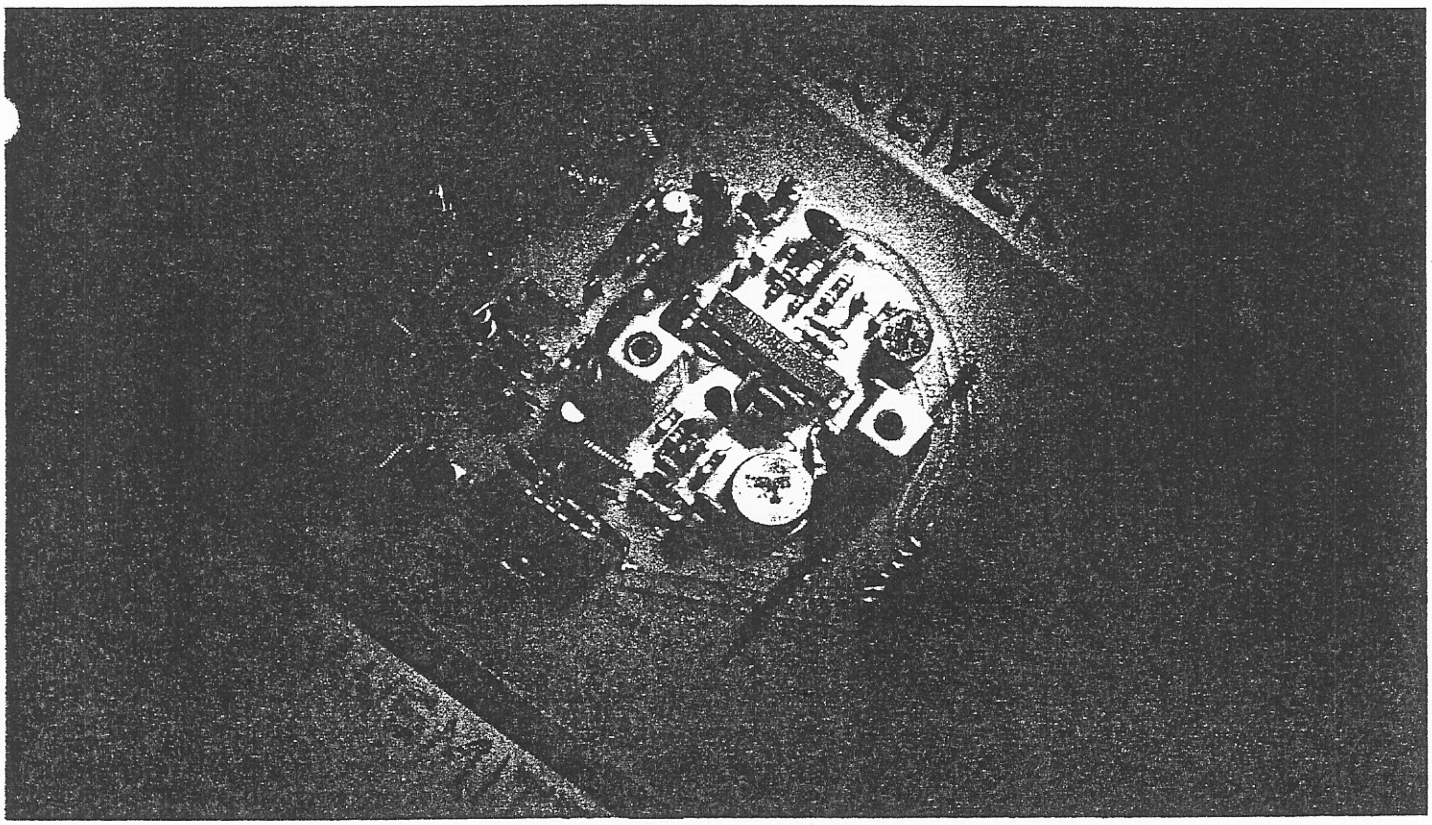
Non frequency agile modems are intended for operation on only one RF channel (or in some instances perhaps two or three channels at the most) and the frequency synthesizer channel control function is not required. Instead, crystal or ceramic resonator controlled oscillators are used to set up the operating channel frequency. A different resonating element/oscillator must be provided if one wishes to cause the modem to operate on another channel. This can be accomplished by physically changing the appropriate circuit elements or by electrically selecting between channel elements that are provided in a multiple fashion within the modem itself. A single channel modem can be produced for less cost than a frequency agile modem but this cost differential diminishes rapidly as the number of operating channels is increased.

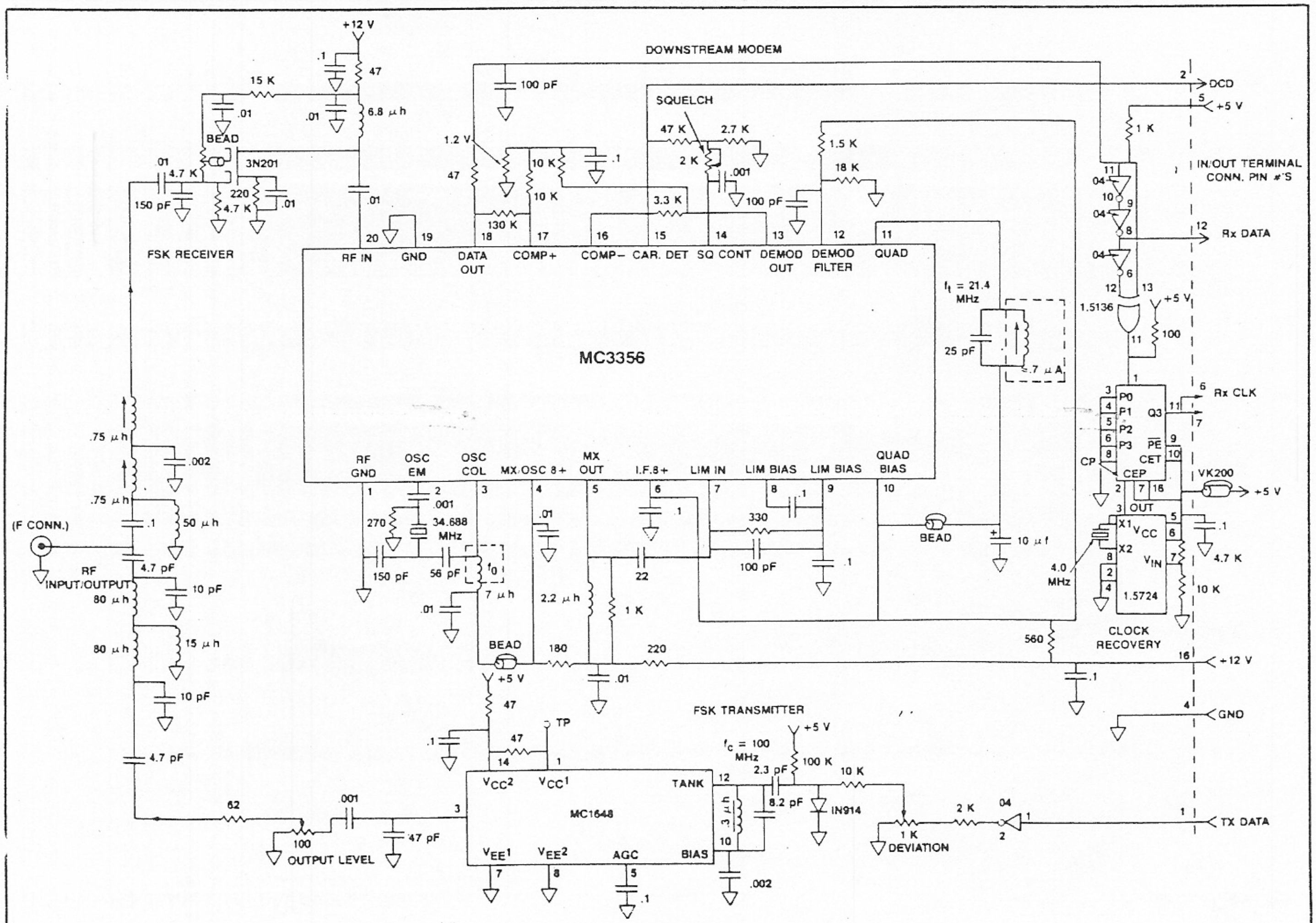
System and Cost Trade-offs

The most important RF modem characteristics to be considered are:

- Number of channels.
- Maximum data rate.
- Channel frequency values/frequency range.
- Paired or independent transmit/receive channel frequencies.
- Transmit/receive frequency offset value.

All of the above must be traded-off against modem cost and suitability for a particular application.





DOWNSTREAM MODEM
FSK RECEIVER
FSK TRANSMITTER
MC3356
MC1648
3N201
SQUELCH
RF IN
GND
DATA OUT
COMP+
COMP−
CAR. DET
SQ CONT
DEMOD OUT
DEMOD FILTER
QUAD
RF GND
OSC EM
OSC COL
MX/OSC 8+
MX OUT
I.F.8+
LIM IN
LIM BIAS
QUAD BIAS
f_t = 21.4 MHz
34.688 MHz
BEAD
(F CONN.)
RF INPUT/OUTPUT
OUTPUT LEVEL
DEVIATION
IN914
TANK
AGC
BIAS
f_c = 100 MHz
TP
+12 V
+5 V
DCD
Rx DATA
Rx CLK
TX DATA
GND
VK200
IN/OUT TERMINAL CONN. PIN #'S
CLOCK RECOVERY
1.5136
1.5724
4.0 MHz

FIG 3-2 (B)

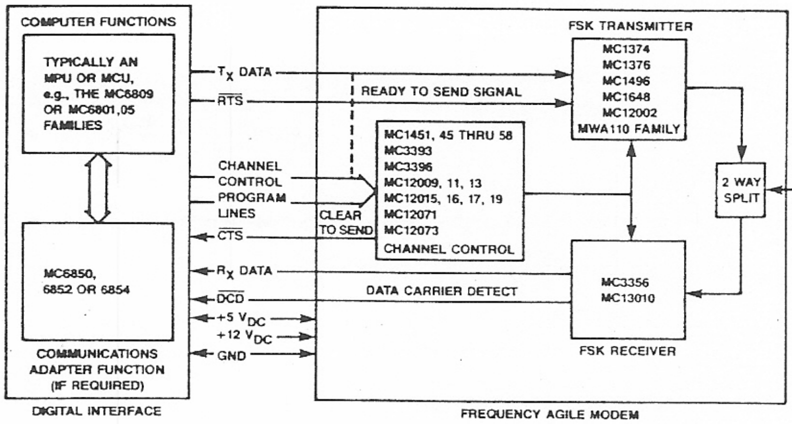


Figure 1 FREQUENCY AGILE RF MODEM/DIGITAL INTERFACE SYSTEM DIAGRAM ALONG WITH SEVERAL ICS PERTINENT TO IMPLEMENTING THE MAJOR FUNCTIONS

The number of channels the modem is capable of being programmed to operate on dictates if a phase-locked-loop (PLL) frequency synthesizer must be incorporated in the design. No synthesizer is needed for single channel operation while greater than three channels will normally require a synthesized approach. Two and three channels units fall into the "gray" area. However, even if not required for channel generation, a PLL may sometimes still be incorporated as the method of generating an FSK modulated carrier for transmission. With the advent of economical LSI PLL ICs and low cost prescaler devices, the use of one or more PLLs does not necessarily mean the modem will be overly expensive.

Although system requirements may dictate a multi-channel modem, cost trade-offs still exsit since the transmitter and receiver can be designed so that channel control is available to each one independently (fully frequency agile) or so that the transmitter and receiver are controlled together with a fixed frequency offset between their respective channels (paired channel operation). For paired channel designs, the choice of transmit/receive offset will impact cost.

The *number* of operating channels alone does not, however, tell the whole story. One "X" channel modem may be significantly more complicated than another "X" channel modem — the actual frequency values involved and also the frequency spread or bandwidth over which the modem must perform can be of equal or greater importance is setting cost. Closely related to these issues is the modem's maximum data rate specification. Higher channel data rates require greater bandwidth per channel and thus a wider total frequency range for a given number of channels. It is worth noting that, for a given total system bandwidth, a small number of high data rate channels will give greater total data output than a large number of lower rate channels. This is because a portion of the system bandwidth must always be devoted to guardbands between adjacent channels. This portion of bandwidth becomes greater, of course, as the number of channels increases. In addition to increased bandwidth requirements per channel, higher data rate signals also tend to be more difficult and expensive to generate and to receive.

The wider bandwidth requirement imposed upon the modem's receiver by higher data rates can affect the choice of frequency for the receiver's IF. Relationships exist between the IF filter's passband and center frequency that must be adhered to. Also, the receiver's IF value and all signal frequencies present at the receiver's input (both desired and undesired) set the location and severity of receiver spurious responses and the degree of receiver front end filtering that will be necessary for adequate performance.

Although the above trade-offs must be dealt with, the application will usually fix many of the key items such as maximum data rate, channel frequencies, and number of channels. This makes it easier to "zero in" on the remaining considerations.

In general, one may summarize as follows:

- Lowest cost units can support data rates up to approximately 200 Kbits per second. This breakpoint is set by the bandwidth limit if available low cost FM broadcast receiver IF filters.
- For lowest cost, receive channel frequencies should be less than approximately 150 MHz and receiver IF value less than approximately 30 MHz. These breakpoints allow economical data receiver ICs such as MC3356 to be used.
- Modem cost can be expected to rise as the bandwidth over which the modem's RF channels fall increases.
- Other things being equal, a lowest to highest cost progression can be expected for single channel, frequency agile paired channels and fully frequency agile modems, respectively.
- A substantial portion of the increased cost for wider bandwidth and higher frequency can be attributed to the filters and crystals required rather than the semiconductor content.

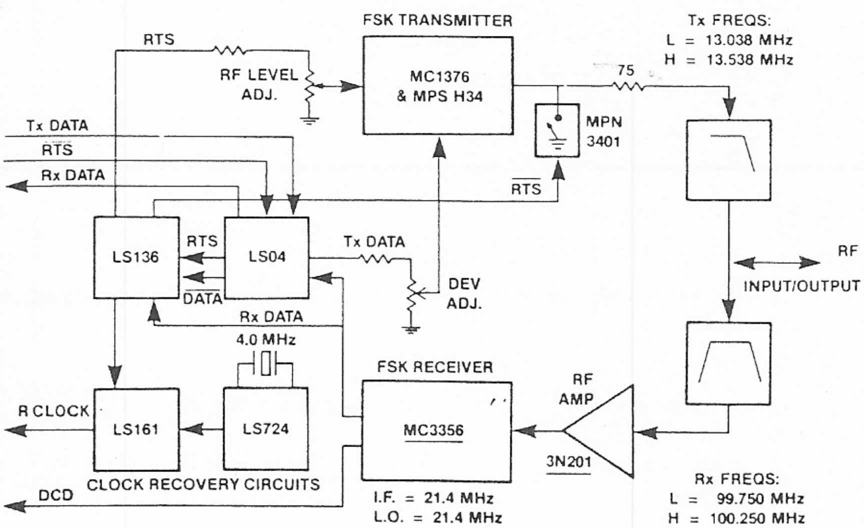


Figure 2(a)