

1) Frequency range

The device uses ten channels in the 900 MHz ISM band, depending on the setting of the 'player number' switch and the current noise levels of the available channels. The RF chipset used in the device has a signal bandwidth of 1.536 MHz and the channel centers are at the following frequencies: 905.728, 907.776, 909.824, 911.872, 913.920, 915.968, 918.016, 920.064, 922.112, and 924.160 MHz.

2) Device description

The device consists of two modules, a battery-powered unit which is held in the hand and has the operable controls for gameplay, and a line-powered unit which is plugged into and communicates with the game box. Since the units communicate bi-directionally it's not accurate to use the terms 'transmitter' and 'receiver', so we use the wireless phone terms 'handset' and 'base unit' to describe the two modules.

As shown on the accompanying block diagram, the handset it consists of the various game control devices (which are multiplexed into the microprocessor), two vibration motors and their associated drivers for gameplay feedback, the battery pack, a microprocessor and an RF chipset (complete with a PIN diode switch to provide half-duplex communication). The RF chipset requires a fixed 6.144 MHz reference frequency, and three times that frequency is a good clock frequency for the microprocessor, so the scheme shown is used: the microprocessor's onboard crystal oscillator is used to generate an 18.432 MHz clock which is divided by three to give the reference clock for the RF chipset.

The base unit block diagram shows that the base unit contains the same RF chipset, a microprocessor which handles the RF communications, and a microprocessor which interfaces with the game box. Two 'downstream' ports are provided so accessory devices (such as memory cards) can be plugged into the base unit, in accordance with the game box manufacturer's requirements. As on the handset, a single crystal is used to generate 18.432 MHz and 6.144 MHz clocks, but the second microprocessor requires a 6.000 MHz clock so it uses a separate crystal.

Since the handset is battery powered, and since communications must be bi-directional to accommodate the vibration motor commands, a packetized protocol is used in which the handset paces the transactions. To maximize battery life, the handset microprocessor places itself and the RF chipset in a sleep mode immediately after a transaction is finished. The microprocessor's onboard sleep timer is used to wake the micro up approximately 9 mS later. At this time data is gathered from the game control devices, and the RF chipset is awakened at the appropriate time to perform its internal self-alignment process. When this is done, the data are packetized in a proprietary format and sent (using a simple FSK protocol) across the RF link to the base unit. The base unit receives the packet, decodes it to ensure the packet is valid, and returns a shorter packet to the handset which includes the vibration motor commands. Upon reception of a valid packet the handset microprocessor places itself and its RF chipset back into sleep mode

until it is again awakened by the sleep timer. Both the base unit and the handset have the ability to request a re-send if the incoming packet is invalid. The entire transaction takes less than 500 uS (assuming no re-send is required).

Since the base unit of the device is not battery powered, it has no sleep mode. Immediately after a successful transaction with the handset unit, the base unit RF chipset is tuned to the other available channels and an assessment is made of the relative channel noises. If another channel is available which has less noise than the current channel, the base unit will instruct the handset to change to the cleaner channel on the next packet, using a handshaking protocol to ensure both modules change channel successfully. The protocol allows the unit to change channels as often as every 70 mS, with no maximum dwell time on a given channel. This isn't the same as frequency-hopping; at any given time all the information resides in a single channel, and the unit may never change channels at all if it finds a very clean channel.

Both the handset and base unit modules will begin scanning all the available channels if no valid packets are received in a designated amount of time. To speed up the re-linking process, the handset sends out packets more frequently when it's scanning. The base unit also scans the available channels but it simply waits to receive a valid packet, and scans the channels more slowly than the handset, ensuring that the two modules will re-link in the shortest possible time.

The handset and base units use the same RF PCB, which has a trace that acts as an internal antenna. No external antenna is used. Because all RF activity is confined to a single small PCB, no complex grounding scheme is needed. All PCB's are conventional double-sided PCB's with ground planes occupying as much real estate as possible on both side of the boards.